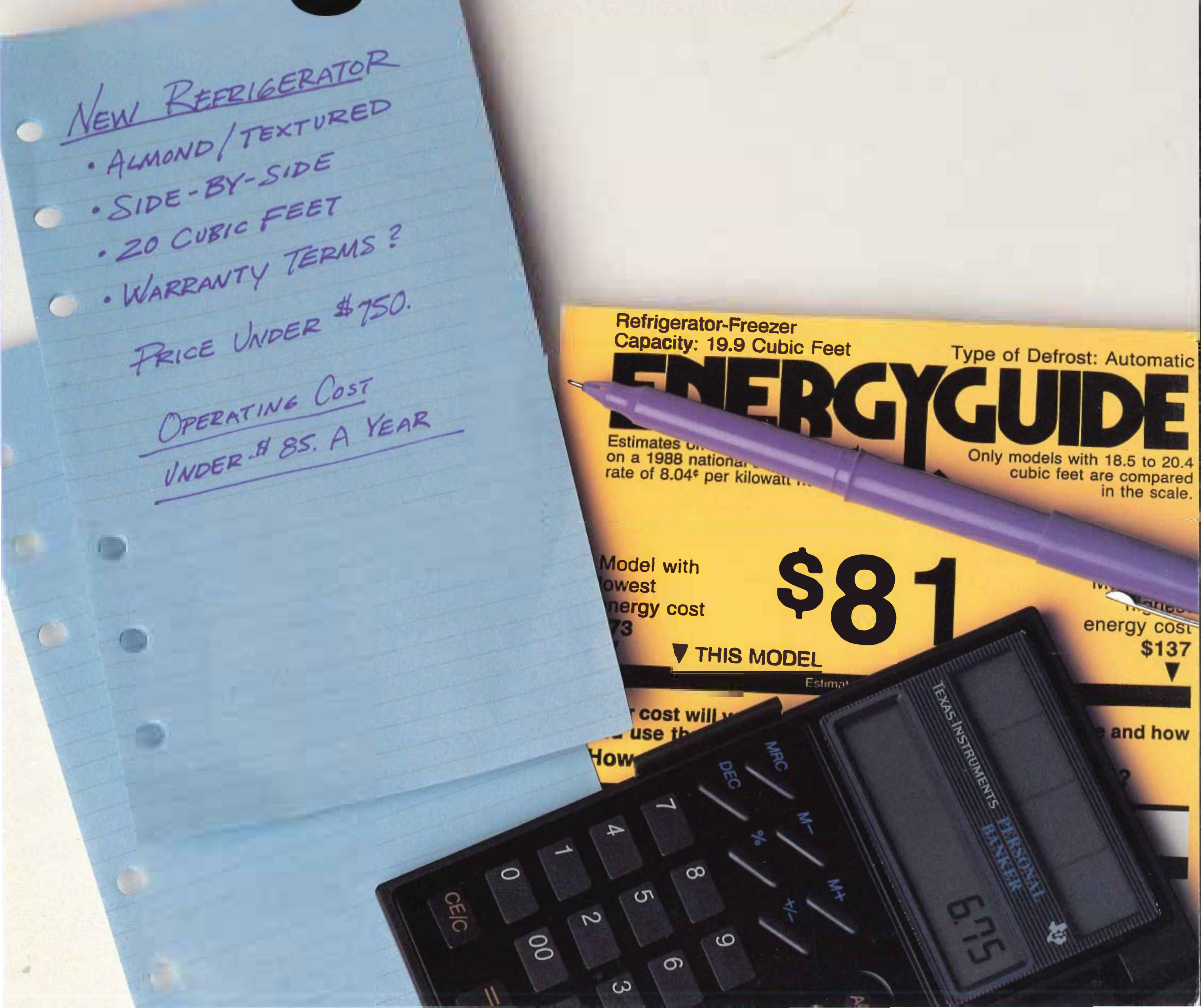
Promoting End-Use Efficiency

Also in this issue *• Coal Quality R&D • Henry Linden Profile • Mercury in the Environment*

ELECTRIC POWER RESEARCH INSTITUTE

EPRI JOURNAL

APRIL/MAY
1990



EPRI JOURNAL is published eight times each year (January/February, March, April/May, June, July/August, September, October/November, and December) by the Electric Power Research Institute.

EPRI was founded in 1972 by the nation's electric utilities to develop and manage a technology program for improving electric power production, distribution, and utilization.

EPRI JOURNAL Staff and Contributors
Brent Barker, Editor in Chief
David Dietrich, Editor
Ralph Whitaker, Feature Editor
Taylor Moore, Senior Feature Writer
David Boutacoff, Feature Writer
Mary Ann Garneau, Senior Production Editor
Eugene Robinson, Technical Editor
Jean Smith, Staff Assistant

Richard G. Claeys, Director
Corporate Communications Division

Graphics Consultant: Frank A. Rodriquez

Address correspondence to:
Editor in Chief
EPRI JOURNAL
Electric Power Research Institute
P.O. Box 10412
Palo Alto, California 94303

Please include the code number on your mailing label with correspondence concerning subscriptions.

Cover: Consumers consider a number of factors when they buy appliances and other end-use equipment. Emphasizing the value of energy efficiency in these purchasing decisions will be important to controlling electricity demand growth in the 1990s and into the next century.

Investing in Energy Efficiency

The energy crises of the seventies urged us to use less energy—and we did. In fact, America cut back to the point that demand growth essentially leveled out for the first time in a century. Today the need for prudence in consumption is still with us. But with electricity recognized as a powerful driver of productivity and innovation, simply using less will not be the answer for the competitive nineties. Energy efficiency—making the energy we *do* use go further—is the conservation ethic of the coming decade.

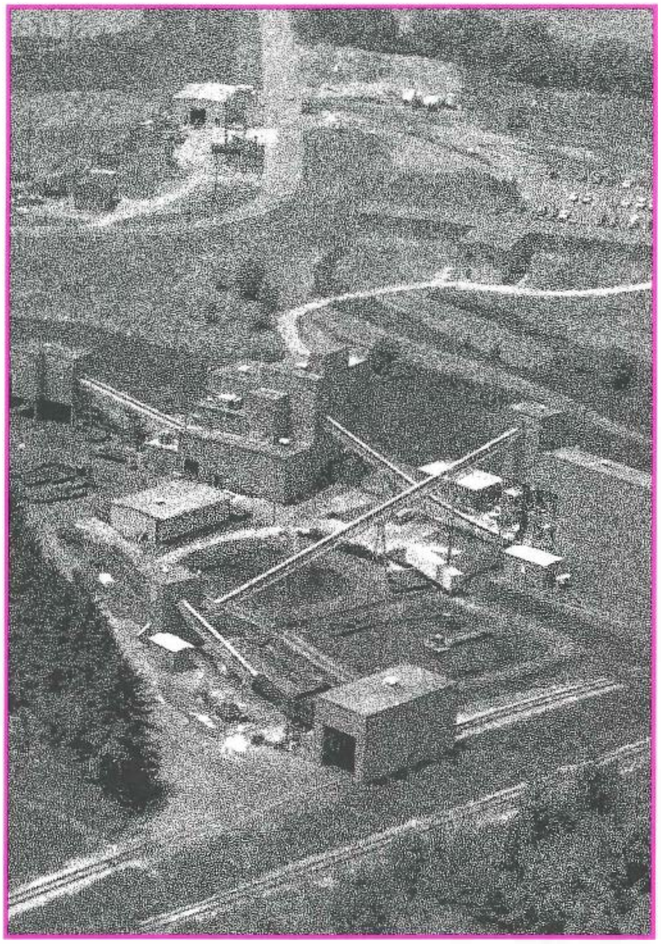
Increasing efficiency at the point of use is the key to the long-term prosperity of utilities, their customers, and the nation. Benefits to the customer are obvious: at the very least, end-use efficiency reduces energy bills. For businesses, both commercial and industrial, energy-efficient electric technologies can also raise productivity, reduce waste, and improve product and service quality—advantages that flow through to the economic benefit of the nation as a whole. And increasing efficiency is the most cost-effective near-term approach to decreasing the impacts of long-term environmental concerns. Electricity, with its unique versatility, flexibility, and efficiency, is the best overall tool for improving our competitiveness and quality of life.

But what about the prosperity of utilities themselves? Selling energy is presently the central concern of the utility business, and one might think that energy efficiency would be seen as a threat to sales. However, more and more utilities are taking a longer view: a utility's fortunes rise and fall, in a very real way, with those of its customers. Energy efficiency can turn an industrial plant's marginal losses into profits, keeping a valuable power customer alive. Helping customers with such problems not only secures and possibly increases sales in the long run, but also improves customer relations.

But we need to go even further with this vision. Pursuing energy-efficient options with customers can provide opportunities to expand a utility's business scope into new areas of energy service—ranging from process engineering to the purchase and installation of equipment and devices. I believe that such a shift of focus—from simply selling electricity to providing expanded energy services—is a central concept for the utility industry's future and will allow utilities to steadily increase the value of electricity to customers. The beginnings of this new vision can be seen and acted on today in promoting energy-efficiency and other consumer outreach programs. I urge all utilities to participate as an investment in the future of their industry.

Clark W. Gellings, Director
Customer Systems Division

RESEARCH UPDATE

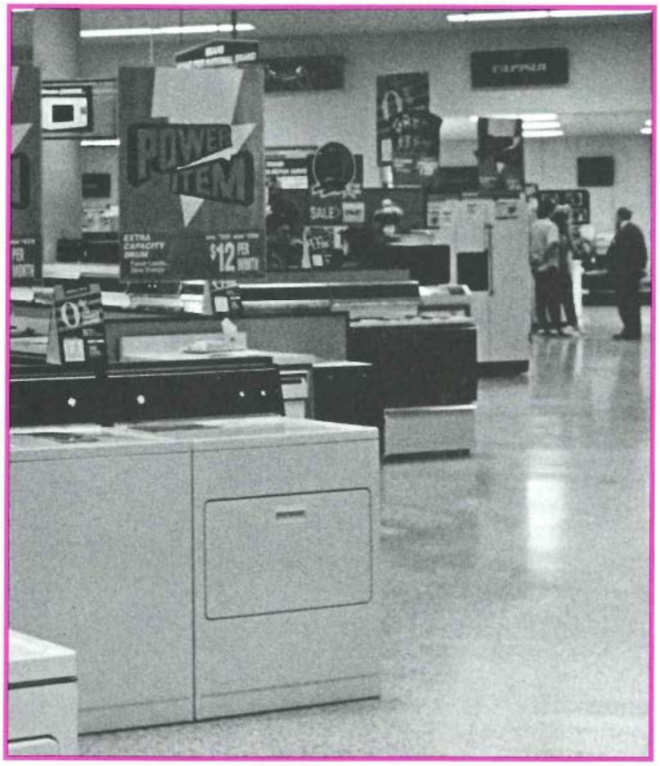


24 CQ Inc.

DEPARTMENTS

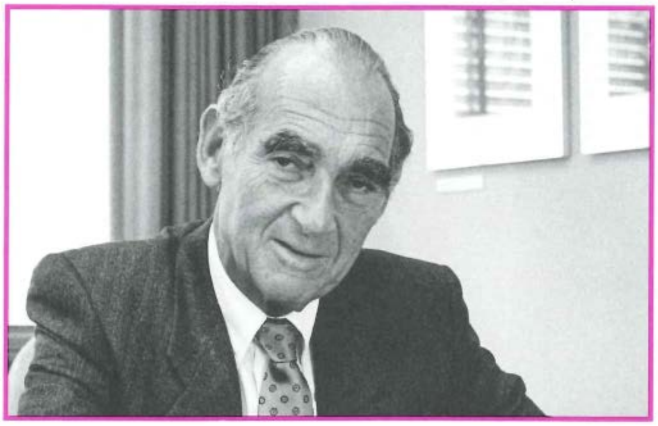
EPRI JOURNAL

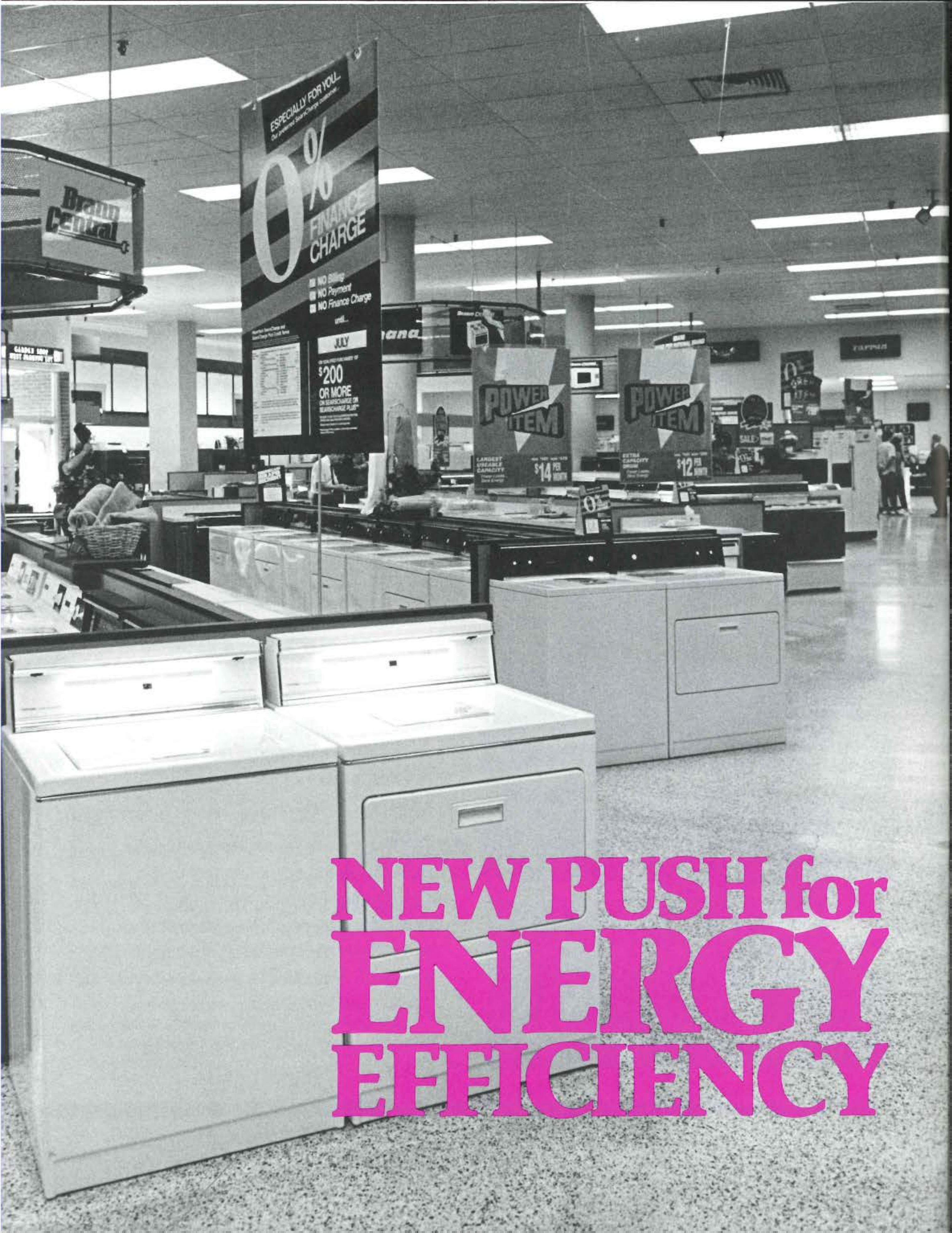
Volume 15, Number 3 April/May 1990



4 Energy Efficiency

18 Henry Linden





NEW PUSH for ENERGY EFFICIENCY

By its very nature, electricity is efficient. In the words of Tim Yau of EPRI, "It's like a troop of soldiers marching in step." Electrons, like Yau's soldiers, are organized and directed as they zip through transmission lines and into a multitude of practical and sophisticated applications, from turning motors to powering laser beams. But the inherent efficiency of this refined energy form doesn't guarantee that we will use it efficiently.

Our energy efficiency has improved dramatically since the oil crisis of the 1970s. Overall, our country uses only 7% more energy than it did in 1973, yet the gross national product has increased some 46%. Our better use of electricity alone has already saved the United States at least $21 billion in the cost of new power plants. The advanced electric end-use technologies available today could help the country save even more on its energy bill. Just how much more is difficult to determine. But EPRI recently completed an efficiency study aimed at tracking this answer down. The researchers focused on the following question: How much energy would be saved if consumers were to replace their present end-use equipment with equipment ranked among the top 20% in terms of energy efficiency? The study results show that if today's most efficient electric end-use technologies were applied in every possible case, they would have the potential to save the United States anywhere between 24% and 44% of the electricity it will be using in the year 2000. The low-end estimate alone, which translates into 800 billion kWh, is enough to meet the entire energy needs of the 11 western states in 2000.

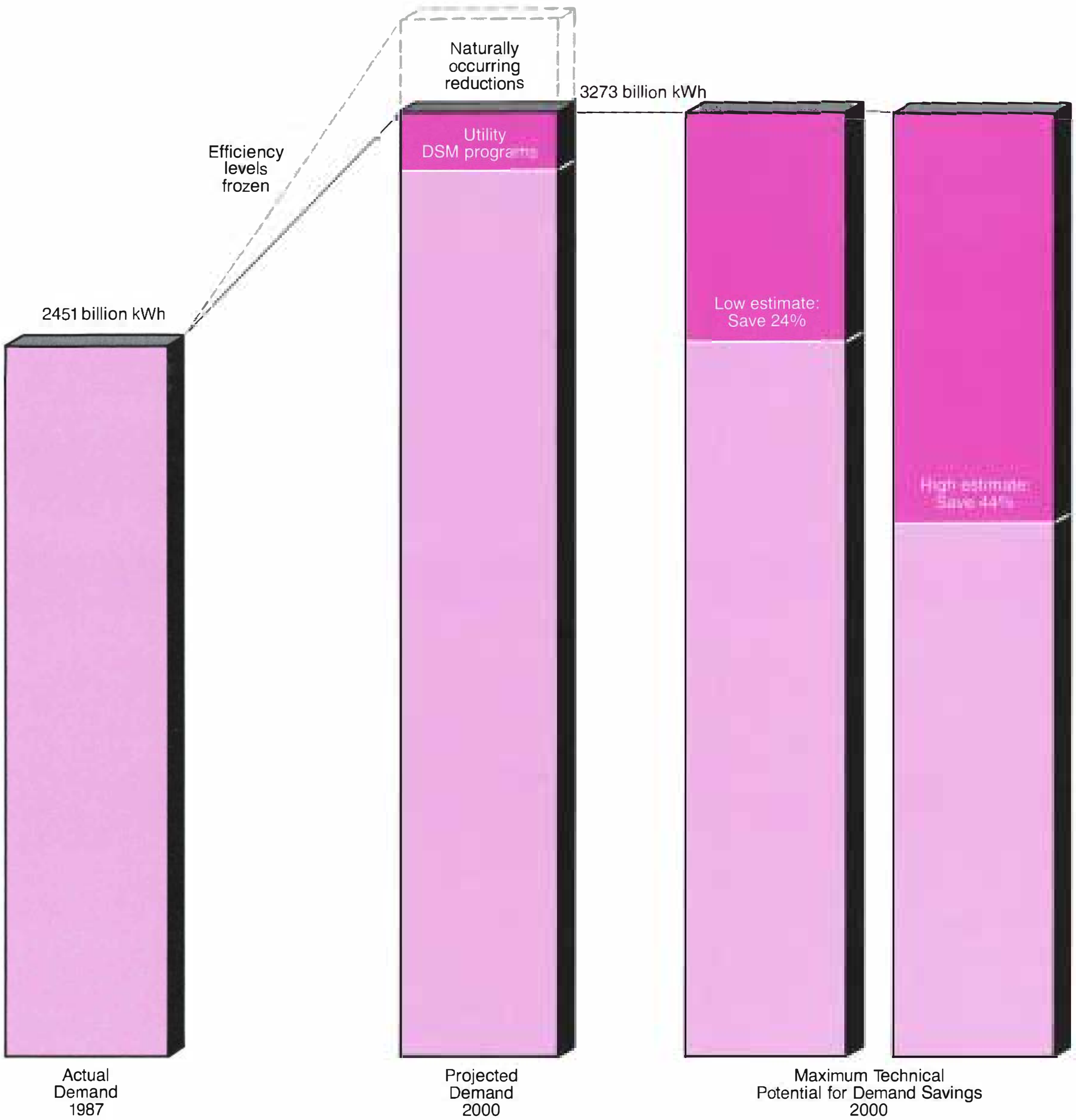
The gap between EPRI's high and low estimates is indicative of how difficult it is to determine the efficiency potential of technologies that haven't yet been widely deployed and thoroughly tested in the marketplace: new equipment may perform quite differently under various real-world conditions and use patterns.

THE STORY IN BRIEF

Full use of the most efficient end-use technologies would allow us to significantly reduce electricity consumption, but consumers in all three energy sectors—residential, commercial, and industrial—have been slow to adopt such advanced equipment. While most manufacturers include very efficient models in their product lines, buyers often consider other selling features to be more important. To increase customer interest in energy-saving technologies, many utilities are pushing efficiency through their demand-side management programs. For utilities that are capacity constrained, this makes perfect sense—promoting energy efficiency is simply less expensive than building new capacity. But the benefits are far less clear for utilities that have plenty of power to sell. Regulatory agencies, knowing that efficiency is good for the consumer and for the country as a whole, are now looking at ways to encourage utility investments in promoting efficient electricity-based technologies.

Projecting Consumption for 2000

Projections of future electric energy demand begin with an estimate of consumption with efficiency levels frozen at a current year's actual rate. But such factors as mandated appliance efficiency standards and normal market penetration of efficient technologies are expected to naturally reduce needs by about 8.6% without any utility action, bringing U.S. consumption for the year 2000 to a projected base level of 3273 billion kWh. Utilities' existing and planned demand-side management programs are expected to reduce this level by another 6.5% or so. But what is technically possible, disregarding market forces? EPRI studies show that 100% penetration of the most efficient technology available could reduce energy consumption in the year 2000 by 24–44%.



There are conservation groups that put the potential efficiency gains even higher than EPRI's high-end estimate. But despite the differing figures, it's clear that there is great potential for savings. And EPRI's report, the first official, industry-wide analysis of the potential for efficiency gains, reflects a serious effort among utilities to help capture some of the savings.

Utilities are among the many consumer, government, and business groups interested in efficiency today. Whether it's manifested as concerns about dwindling utility capacity, about the competitiveness of U.S. industry, or about the environment, the incentive to use electricity more wisely appears to be everywhere. "Efficiency is something everyone wants to have," says Yau, manager of strategic planning for the Customer Systems Division. "It's become such a good word—the 'E word.' Different people want efficiency for different reasons. Some want it for the economy, others for the environment. But it turns out that efficiency can do something for everybody. It's a win-win situation."

Today's rekindled interest in energy efficiency, which some are calling a renaissance conservation movement, is marked by a spirit of cooperation. Utilities and conservation groups that once were at odds with one another now are collaborating on ambitious efficiency projects. Regulators across the country, meanwhile, are working on monetary incentives to get utilities more interested in promoting efficiency. But there's a crucial difference between today's movement and the conservation efforts of the seventies: the emphasis on energy efficiency. Today, energy efficiency doesn't necessarily mean conservation, or cutting back. It means using our energy resources more wisely and productively and taking advantage of the highly efficient technologies now available to us.

"We shouldn't have to reduce our standard of living to save energy and protect our environment," says Clark Gellings, director of EPRI's Customer Systems Division. "Innovation in science and technology is the key, and developments already in sight can save us vast amounts of electricity. We've worked very hard to achieve a good quality of life for ourselves and our children. Let's not assume it must be compromised."

EPRI's study shows that electric technologies in the residential, commercial, and industrial sectors offer roughly equal opportunities for savings—each accounting for about a third of the overall efficiency potential for the year 2000. In our homes, advanced appliances and better insulation strategies could make us more energy-efficient. In our businesses, space heating, cooling, and lighting systems show great potential. And in our industries, motor drives could be a big saver. (See sidebar for details.) EPRI's estimates are based on efficient technologies that are either already available commercially or far enough along in their development to indicate they could make a difference within the next decade. There are few laboratory prototypes that could have an impact by the year 2000.

But what's really possible?

EPRI isn't the only organization probing for answers to the efficiency-potential question. Pacific Gas and Electric is among those who have initiated their own projects to test the maximum efficiency potential of advanced technologies. Called Advanced Customer Technology Test for Energy Efficiency (ACT^2), PG&E's $10 million program will include both electric and gas technologies. The project is expected to get under way sometime this year and will take from three to seven years to complete. PG&E's Merwin Brown, project manager of ACT^2, believes this effort will be the first comprehensive real-world test of state-of-the-art efficient technologies. Homes, factories, farms, and offices throughout PG&E's service territory will be fitted or retrofitted with the most efficient technologies available, some of which haven't yet left the nation's science labs. Emphasis will be on integrating the various technologies for maximum results overall. The project will be overseen by a steering committee that includes representatives from the DOE-funded Lawrence Berkeley Laboratory (LBL); the Natural Resources Defense Council, an environmental group; and the Rocky Mountain Institute, an energy efficiency organization.

Like EPRI's study, ACT^2 is focused strictly on technological potential. In fact, in order to determine the true, maximum *technical* potential, EPRI's study assumes a 100% penetration of its advanced technologies in the marketplace. What's actually achievable in the real world of consumers—the *market* potential—is an entirely different question. Consumers' decisions on energy-using technologies will depend on a variety of needs and concerns, such as the cost of the equipment, its appearance, the comfort or convenience it provides, the price of energy, the availability of information on the technology, the potential inconvenience of installing it, and whether or not there's a need to replace existing equipment. These factors often create barriers that limit the success of efficient technologies in the marketplace. As a result, even EPRI's low-end estimate of efficiency potential is higher than what real-world consumers could actually achieve.

Predicting the level of efficiency actually achievable among American consumers is considerably more difficult than forecasting the technical potential. Some estimates—such as the so-called cost-effective estimate, which assumes consumers will adopt efficient technologies only when they are cost-effective—come a bit closer to predicting what actually could happen. But there are other factors to consider too. Aside from the consumer's needs, there are even less-predictable economic, political, and natural events that can affect our decisions dramatically, as we discovered in 1973.

Efficiencies for the Future

Imagine if, in the year 2000, all electric end-use technologies were replaced instantly with the most efficient electric technologies on the market. This move would save anywhere between 24% and 44% of the electricity we would have used in that year, a recent EPRI study has concluded. Of course, such a thorough penetration of advanced technologies is not possible in the real world of consumers. But EPRI's study was intended to determine the maximum *technical* potential for energy savings. Here's a look at the types of technology available to achieve substantial savings in each customer sector.

Residential

In the residential sector, anywhere between 27% and 46% of the electricity we'll be using in 2000 could be saved. That amounts to between 289 billion and 484 billion kWh. The biggest contributors to the potential savings are technological advancements in water heating, space heating, and miscellaneous appliances, of which lighting represents 45%.

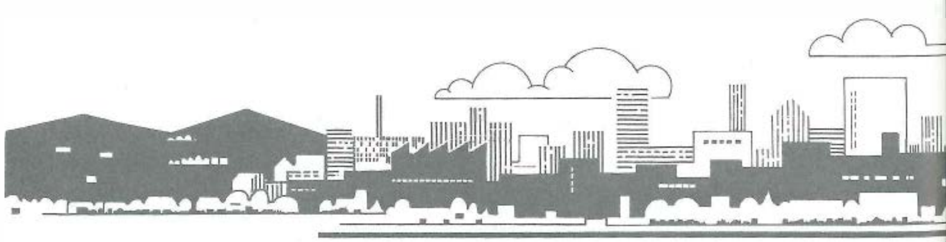
To achieve this level of efficiency, our homes would be weatherstripped and caulked; they'd have storm windows and doors; and ceilings and floors would be well insulated. Efficient electric heat pumps and solar panels would reduce energy use for space and water heating. Compact fluorescent bulbs with incandescent-like color spectrums would light our lamps.

Among the biggest energy savers available for our homes today is the electric heat pump. The heat pump can extract "heat" from even cool air outside a building and pump it inside. EPRI has collaborated with Carrier Corp., the country's leading air conditioner manufacturer, to develop a heat pump that is 30% more efficient than conventional models. Introduced to the market last year, this heat pump is the most efficient heating, ventilating, and air conditioning appliance available today. It can recover heat rejected from its air conditioning function and use it to heat water in the summertime, the result being "free" hot water for the customer. An optional control can automatically limit the amount of electricity the heat pump uses during a utility's hours of peak demand. Benefits to the customer include reduced energy costs, better longevity, and greater comfort—no "cold blow" or noise problems.

Commercial

In the commercial sector, anywhere between 23% and 49% of the electricity we'll be using in 2000 could be saved. That amounts to between 234 billion and 505 billion kWh. The biggest contributors to the potential savings are lighting, space cooling, and various "plug loads," such as office equipment, computers, and copy machines.

To achieve such savings, our typical commercial buildings—whether they be office towers, restaurants, or retail stores—would integrate a variety of energy-efficient technologies. Sophisticated lighting systems would include more-efficient bulbs and ballasts and a variety of controls. Occupancy sensors that turn lights on and off automatically and computer-based timing are two examples. Another type of control, based on photocell technology, can track the amount of daylight entering a room and trigger an appropriate supplement from the electric lighting system. Windows would be specially treated to allow visible light through while keeping undesired heat out. Ele-



vators and escalators would run on high-efficiency motors.

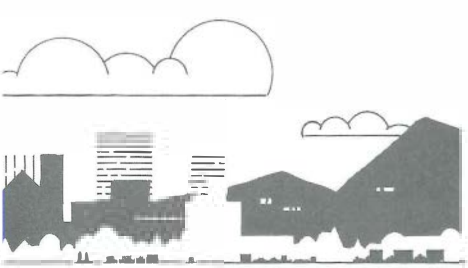
An ongoing EPRI project has shown that much electricity can be saved in commercial buildings through the integrated design of heating, ventilating, and air conditioning systems with lighting systems. Results indicate that if more-efficient strategies were applied to only 5% of existing U.S. commercial spaces and to 25% of new construction each year, they could save 1400 MW annually, the equivalent output of one and a half large power plants. These better designs would dramatically reduce peak loads for utilities, particularly during the summer, when air conditioning systems create substantial demand.

Industrial

In the industrial sector, anywhere between 24% and 38% of energy used in 2000 could be saved. That translates into 277 billion to 447 billion kWh. The biggest opportunity for improvement lies in motor drives, which account for 67% of the industrial electricity used today. Essentially, motors keep American industry moving—turning its fans and blowers, running its pumps and compressors, spinning its blenders, and propelling its conveyors and process lines.

To take advantage of the full potential for savings, our industries would be using high-efficiency motors with adjustable-speed drives (ASDs) that allow for efficient and smooth variations in motor speed. Work areas would be illuminated with efficient lighting systems that incorporate high-frequency ballasts, improved reflective fixtures, and sophisticated lighting controls like those in the commercial sector.

Electronic ASDs use semiconductor and switching circuits to vary the frequency of power to ac motors. Without them, these motors are limited to operating at a constant speed that can be regulated only through mechanical and hydraulic devices like clutches, gears, and valves. ASDs give motors only as much power as they need to suit the task at hand. They also operate much more quietly than do mechanical and hydraulic devices, and they allow for smooth startups and shutdowns, reducing the wear on equipment. Electronic ASDs alone can slice an industry's energy use requirements by 20%, EPRI studies have shown. With ASDs, U.S. industry could save 95 billion kWh of energy per year, or about $5 billion annually. □



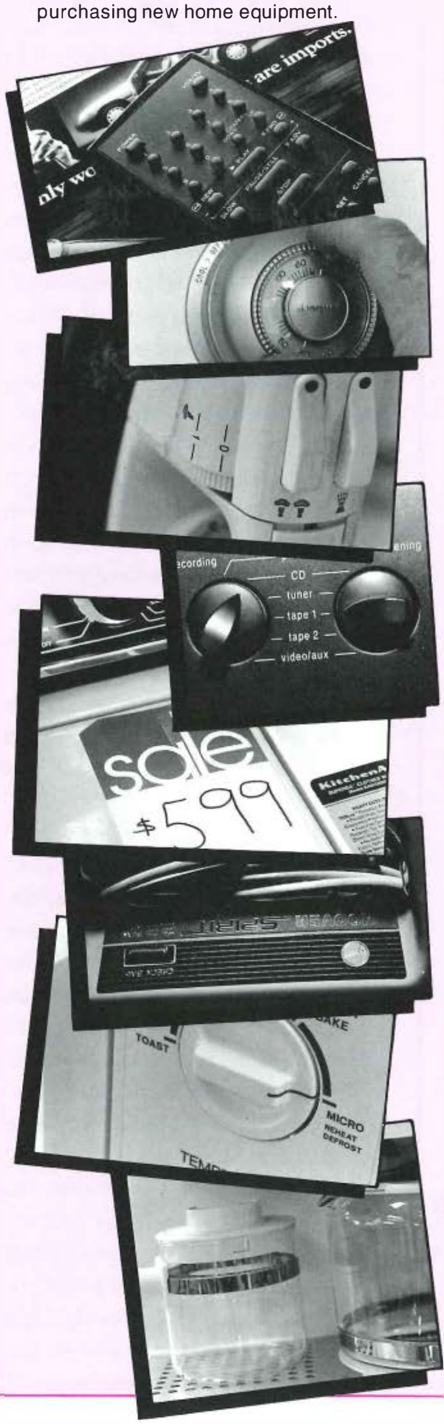
"There is no holy grail out there," says Steven Braithwait of EPRI, technical manager of the Market Assessment Program. "There is no magic number, no magic way of finding out what the achievable potential is. They're all estimates, and there's a lot of uncertainty."

Despite the difficulties involved, some projects have been aimed specifically at tracking down the true potential for efficient energy use among consumers. The Hood River Conservation Project, a $20 million, five-year experiment launched in 1983, is one example. Funded by the Bonneville Power Administration and run by Pacific Power & Light, the Hood River Project was a residential weatherization program that targeted electrically heated homes in Hood River County, Oregon, a community of 15,000. To encourage participation, Bonneville covered the cost of the weatherization measures and offered free audits to every eligible home in the county. When necessary, project workers went door-to-door to sign residents up. Ceiling and floor insulation, storm windows, caulking, and weatherstripping were among the measures installed in about 3000 homes. No water- or space-heating equipment was replaced. The project drew 85% participation from eligible homes and resulted in annual savings averaging 2600 kWh per house.

While participation in the project was healthy, it wasn't automatic. "Just paying for 100% of the measures doesn't mean you're going to get 100% participation," says Ken Keating, program evaluation manager at Bonneville. "You've got to sell it to people, even when it's free," he says. "Just stand in an airport lobby and try to hand out $50 bills. You'd be surprised at how many people walk by." Some residents didn't participate simply because they didn't want project workers in their homes. Others were in the process of selling their houses and didn't want to be bothered. Before the Hood River Project was launched, a sociologist was hired to study the community. Pro-

What Do Consumers Want?

The ability to conserve energy is only one of many values the residential consumer trades off in buying home appliances and equipment. Energy efficiency has come to be appreciated in a few product areas—mileage economy for automobiles, for example—but in the home market this concern frequently loses out to convenience, comfort, and styling. Listed are some of the needs people try to satisfy in purchasing new home equipment.



Convenience Consumers appreciate the convenience offered by such items as microwave ovens and remote-control units. Energy-efficient technologies that reduce convenience are not readily adopted.

Comfort There is a range of values consumers place on keeping their homes comfortable through the use of energy for heating, cooling, or dehumidification.

Appearance Consumers may select appliances solely on the basis of aesthetic appeal or how styling matches the general appearance of their homes.

High Technology One consumer segment is attracted to the most technologically advanced options available. Sometimes this includes high-efficiency units, but more often it means "bells and whistles."

Conservation/Cost Issues Some residential consumers are aware of the cost benefit of reducing electricity use, but the initial cost of an appliance is usually the greater budgetary concern.

Personal Control Personal control of their appliances is very important to some people, while others are willing to let electric utilities take a measure of control in exchange for lower rates.

Safety Many consumers have concerns about the safety of items such as electric blankets, microwave ovens, and gas appliances.

Shopping/Time Investment Some consumers simply hate the hassle of making choices when they buy new appliances and are reluctant to comparison shop, calculate economies, or even switch brands.

gram marketing was conducted strategically so that "proud" residents wouldn't feel as though they were getting a handout. The message workers tried to relay was that the community could set an example for the rest of the country.

EPRI also is trying to help answer some of these market penetration questions. In fact, one project currently in the works is expected to result in a software program that will help determine the likely market penetration of new energy-using and energy-efficient technologies. According to Larry Lewis, manager of the Market Assessment Program at EPRI, utilities will be able to use this tool to determine how well their customers will respond to a particular technology over a period of time. The impact of utility programs and competition from alternative technologies are among the factors the program can take into consideration. Lewis's program is based on mathematical models developed from past consumer reaction to a variety of new technologies. It is expected to be released by the end of the year.

A related software program, PULSE, was released by EPRI just last year. PULSE is intended to help utilities plan more-effective programs for their residential customers, such as those encouraging more-efficient use of electricity. Utilities can use the software to assess their customers' preferences and then estimate the market potential for a variety of alternative programs. The tool allows utilities to tailor their programs to their customers, down to the specific technologies to which the customers are most likely to respond. The computer model is based on extensive research into which program features—such as warranties and rebates—are most likely to influence customer participation. Consumer response to specific technologies, including trade-off factors, was gathered through 2700 home interviews across the United States.

Lewis says the programs are not intended to, and probably could not, give utilities "correct" answers. But they go a long way toward helping them design more-effective programs. "You can talk conservation and energy efficiency all you want," he says. "But unless you're able to understand the customer's needs and design the program to cater to those needs, the program is not going to be very effective."

Attention to the customer

Being able to design effective customer programs is increasingly important to utilities today. But this hasn't always been the case. Before 1973, utilities saw relatively predictable demand growth annually and built new supply to accommodate it. But skyrocketing oil prices changed all of that. Consumers cut back considerably and demand no longer was predictable. In response, utilities shifted their focus toward the demand side of the energy equation. They began developing ways to manage demand so they could ensure adequate and efficient supply. Now known in the industry as demand-side management (DSM), this approach encompasses a variety of techniques to influence customer demand. It includes energy efficiency programs as well as load-building and load-shifting programs.

Virtually all utilities in the country are pursuing DSM to some degree, according to a newly released EPRI report. This year, nearly 15 million residential customers will participate in DSM programs, the report says. With healthy participation, DSM programs have the potential to capture significant efficiency gains. Existing and planned DSM programs alone are expected to reduce summer peak demand in 2000 by approximately 43 GW—the equivalent output of 43 large power plants. That's about a 6.5% reduction in the demand forecast for 2000. Braithwait, who helped compile the DSM study, says this figure is 90% certain.

These projected DSM impacts and the potential technical impacts in EPRI's report are over and above the so-called naturally occurring efficiency improvements in our country. In other words, utility industry forecasts for 2000 already assume our society will be more efficient in 2000 than we are now. Increasingly stringent state and federal appliance and building efficiency standards are one guarantee of our increased efficiency. In addition, as our old, less-efficient technologies wear out, we automatically tend to replace them with more-efficient models on the market. And as energy prices rise, we tend to buy more-efficient technologies. These "naturally occurring" efficiency improvements will represent about 8.6% of the electricity we'll be using in 2000, according to Gellings.

Some utility DSM programs are geared toward achieving a portion of the savings that we know are technically possible but that will not occur naturally. And to a large extent, the success of these programs depends on how well utilities understand their customers. While market research has been an integral part of American business operations for some time, utilities have only recently come to depend on it. Says Lewis, "The utility industry is finally beginning to realize that if it's going to get its programs on the market, it's got to understand the customer's attitudes and perceptions."

The utility industry's shift toward a customer focus was reflected at EPRI in the broadening last January of its Energy Management and Utilization Division into the new Customer Systems Division. Among utilities themselves, the shift is mirrored in the increasing number of customer-oriented programs cropping up across the country. Utilities that once focused only on selling and marketing increased kilowatthours now are offering their customers a variety of energy services, from free energy audits to assistance in building design. Efficiency programs are an increasingly significant part of these services. "Conservation and load management opens up a whole new marketing opportunity for utilities," says Alan F.

Destribats, who is the vice president of demand and least-cost planning at New England Electric System (NEES). "This is something that can bring value; it can bring service; and it can help make customers more competitive in their industries."

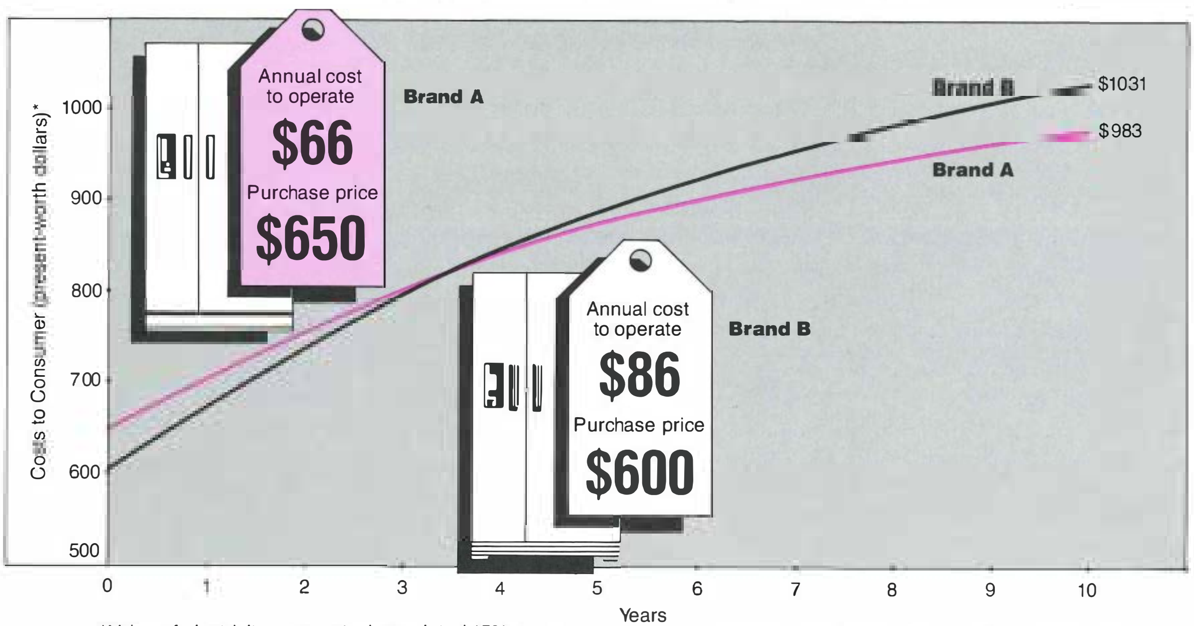
It may seem odd that utilities that traditionally have profited from selling increased kilowatthours suddenly would be interested in selling less electricity. But there are a number of factors nudging them in this direction. Some utilities —particularly those located in New England—are facing generation shortages, and paying for efficiency programs can be much cheaper than building new power plants. In addition, in this decade of the environment, as many are calling the nineties, the Western world has expressed an unprecedented concern about issues like air quality and global warming. In response, many utilities today are aiming to deliver electricity as cleanly and efficiently as possible.

NEES—the holding company of three northeastern utilities—has collaborated with the Conservation Law Foundation of Boston to develop a package of efficiency programs known as "Partners in Energy Planning." Launched in 1987, the systemwide effort reaches commercial, industrial, and residential sectors and has been held up as a model for the rest of the country's utilities. By January 1989, two years after the project was initiated, the company managed to reduce system demand by 202 MW. The programs have contributed to slowing demand growth from an average of more than 5% annually in the mid-eighties to 2.8% in 1989. This year, NEES will spend $65 million on conservation and load management, which amounts to more than 4% of its gross revenue, Destribats says.

But not all utilities have the incentive of capacity constraints. Gellings estimates that as many as 30% of the country's utilities have adequate capacity to handle demand, at least in the near future. And it would be naive to think that these utilities would readily embrace the idea of selling fewer kilowatthours, he says. "There are stakeholders involved in every utility, whether it's investor-owned, a cooperative, or a municipal.

Efficiency Gets Short Shrift

The value of efficiency is largely discounted by the public in its purchasing decisions. Studies show that an appliance's initial cost usually carries much more weight than its energy efficiency, despite the fact that reduced operating cost can save the consumer much more money in the long run. In the example shown here, by choosing the lower-priced refrigerator, the buyer saves $50 on the initial purchase but ends up spending about $50 more in total costs over the next 10 years because of higher energy use.



*Value of electricity payments depreciated 15% per year to account for true devaluation of money over time.

Source: 1989 Directory of Certified Refrigerators and Freezers.

And utilities have an obligation to ensure a fair return on the investment of those stakeholders." The way most electricity rate formulas are designed today, utilities lose money when they sell fewer kilowatthours. And as Art Rosenfeld, a physics professor and a director at LBL, says, "There's no way a utility gets rewarded for slitting its own throat."

Efficiency incentives

Regulators in recent years have begun to address this problem. Rather than attempting to force efficiency programs on utilities, they are working on ways to make the programs profitable. "The regulators in the country have realized that, basically, we've been very hypocritical about our treatment of utilities," says Rosenfeld, who was a member of a task force that drafted the National Association of Regulatory Utility Commissioners (NARUC) Conservation Committee's first incentive plans. Among the incentives developed to promote efficiency is allowing utilities to earn a return on their investment in efficiency programs, just as they make a return on their investments in power plants and electric distribution systems. And to ensure that utilities aren't simply throwing money at efficiency, there are other, results-oriented incentives. For example, a utility may get a bonus for reducing demand or for shaving peak load. Or it may get a bonus for lower customer bills resulting from efficiency programs. Other proposals have included incentive salaries for utility executives and other employees.

For the first time this year, one NEES utility, Narragansett Electric, will earn a profit through regulatory incentives if its programs are successful, Destribats says. And regulatory hearings under way in New Hampshire and Massachusetts could lead to incentives for the holding company's two other utilities, Granite State Electric and Massachusetts Electric. Narragansett's target this year is a 12,900-kW load reduction. If the utility meets this goal, it will earn a $1.7 million profit. If it achieves less than the goal, its profit will be less. Meanwhile, it will cost an estimated $10.7 million to run the efficiency programs, an expense that will be recovered through rates.

Today, at least 10 states are considering overhauling their rate formulas to provide these kinds of efficiency incentives. And three, including Rhode Island, already have incentives in place. In one of the most recent actions, California's four largest utilities have helped devise a plan that will allow them to profit while spending $550 million on energy efficiency programs in the next two years. If successful, it will save ratepayers more than $1 billion on their energy bills over the next several years.

In New York also, a statewide effort has been under way for some time. The state's Public Service Commission in 1988 invited its electric utilities to propose their own ratemaking reforms. Among the first utilities to get preliminary approval last fall was Niagara Mohawk Power. Final approval of the incentives, which is expected soon, will allow Niagara Mohawk to profit from efficiency services for the first time this year. In the meantime, the utility is implementing its 1990 efficiency programs. A total of 12 utility programs are included in Niagara's plan. It will cost $30 million in 1990, a sum that includes everything from the purchase of efficient technologies to marketing and administrative costs. Under the preliminary plan, the utility will be allowed to recover program costs and to clear a $1 million profit if it achieves its goal of savings of 133 million kWh this year. By 1992, the programs in the 1990 plan should achieve annual savings of 240 million kWh. Incentive money is collected up front and is paid back if the utility fails to achieve its goals.

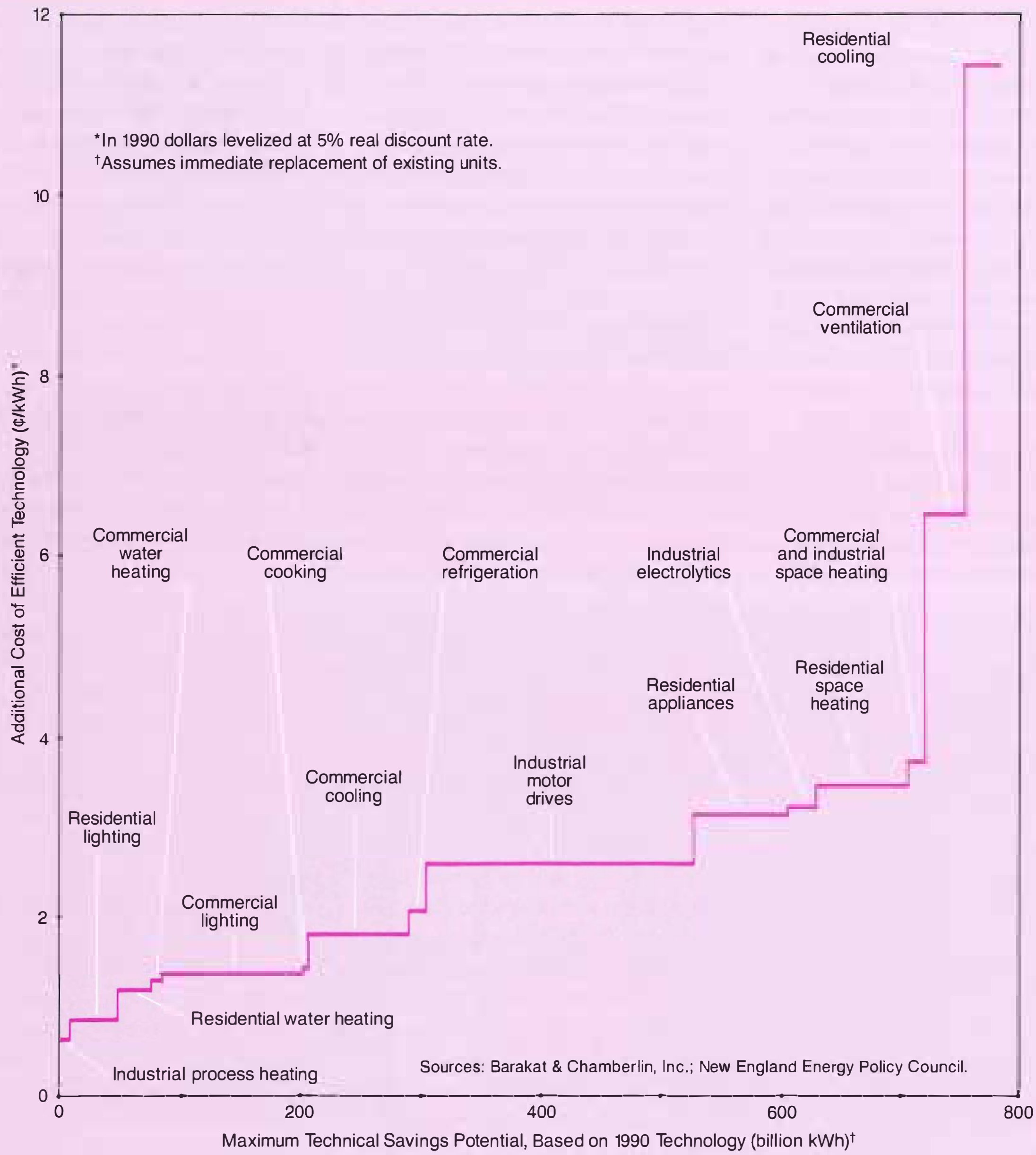
So where does all the money come from? Eligible customers in each sector will experience a rate increase, the largest of which is 1.4% for 1990, says Theresa Flaim, director of demand-side planning for Niagara and an architect of the incentives proposal. While participating customers will see lower bills because of the savings due to the conservation measures, nonparticipating customers are likely to experience increases in their bills, according to Flaim.

Here's how one of Niagara's efficiency programs works. The residential Low-Cost Measures Program is directed at residential customers with electric water heaters. The utility will give participating households insulation to wrap around their water heaters and pipes, a low-flow showerhead, and one high-efficiency compact fluorescent light bulb. The resulting energy savings per participant is estimated at 957 kWh a year, which translates into roughly $72 in lost energy sales for the utility. Simultaneously, however, the utility saves about $40 on fuel and capacity costs. The result is an actual net loss in revenue of about $32, which the utility is allowed to collect through rates. Through the participation of this one customer, the utility's pool of shareholders will earn an extra $4.88 annual profit for eight years, the average "life expectancy" of the measures in this program. The utility's estimated program cost per participant is $50, which is also recovered through rates.

For utilities with ample capacity to spare in their off-peak hours, load shifting may appear more attractive than conservation. But Rosenfeld says all utilities should be encouraged to take advantage of one-time opportunities to improve efficiency. New construction, for instance, offers the chance to install energy-efficient measures that will show benefits for decades to come. "If we lose these kinds of opportunities," says Rosenfeld, "we're doing a terrible thing to our grandchildren, because buildings built today will be living on electricity whose source is going to be very expensive." Rosenfeld predicts that domestic oil production will become negligible by 2010.

The Cost of Saving

Efficient end-use technologies have the technical potential to save a tremendous amount of energy, but the savings don't come free. The graph shows the additional capital and installation costs consumers must pay for the more efficient technology (amortized over the life of the unit). As long as these costs are lower than the cost of electricity, use of the technology will save the customer money.



Sam Swanson, an energy conservation expert for New York's Department of Public Service, agrees, pointing out that only a few years ago New York's utilities were not capacity constrained. Utilities with ample capacity must design DSM programs strategically, Swanson says. "Resources should be focused on building efficiency into projects under way, including major remodeling as well as new construction. Retrofitting options must be examined more closely but could also benefit these utilities, especially if the cost of providing electricity exceeds the cost of the retrofit."

Ratemaking reforms may give more utilities the incentive they need to promote energy efficiency. But they raise another great challenge: how to prove that the efficiency programs work. Determining what savings, if any, are attributable to a utility program when there is an overall increase in electricity use will be a difficult task. In fact, Swanson expects that accurately measuring efficiency savings will be the most difficult aspect of the incentive plans. For this reason, each plan includes a thorough program evaluation mechanism. Programs and expenses will be monitored closely through metering, bill analysis, market surveys, and other techniques. These mechanisms will also help ensure that utility incentives are performance based. Says Swanson, "We want to reward the companies not for spending money, but for achieving results."

Narragansett Electric's program is using engineering estimates based on 10 years of experience with specific measures like water heater insulation and efficient lighting to help calculate savings, Destribats says. In addition, metering and comparisons of participating and nonparticipating customers will help measure program results.

Proponents of the regulatory reforms hope ultimately to make monitoring of demand-side programs as reliable as monitoring of the supply side. "What we're trying to do is make demand-side management a standard resource the way a coal plant or a hydro plant is," Swanson says, adding that this goal will most likely take years to achieve. The demand side, which involves many people, is inherently more complex than the supply side, with its more easily monitored equipment. But Swanson insists that once program administrators gather the necessary information on customer behavior and energy use, activity on the demand side can be tracked effectively.

Skeptics of the regulatory reforms, meanwhile, say that the difficulty of proving efficiency savings is a fundamental weakness in the incentive plans. They argue that increased regulatory involvement imposes "unnatural" solutions that are bound to further complicate the electricity demand-supply equation. In addition, they say, not all utilities can afford to increase their customers' rates. "The ratepayer pool of resources is not a bottomless pit," says Gellings, who supports the idea of regulatory incentives but insists they must be implemented carefully. "No matter how big the utility and how many ratepayers it has, if the tab for everything is always passed along to the customer, the utility's electricity price will eventually be driven up to the point where it's no longer competitive."

Competition in the utility industry may not be obvious today. But it does exist in various forms. The most obvious competitor is the gas industry (in instances where the gas utility is separate from the electric utility). In fact, last year for the first time, the number of new houses in this country with gas heat exceeded the number with electric heat. Other competitors include independent power producers, who are taking some business away from utilities by supplying electricity directly to utility customers.

Gellings says it's important to recognize that regulatory reforms are not a panacea. A more permanent and wide-reaching solution to the efficiency issue, he says, will include free market activity: getting utilities into the energy services business. "I think there's a business out there," Gellings says. "I think it's clear that there's money to be made." Making money from energy services may sound similar to regulatory incentives, but the market-based solution would go much further. It would involve utility representatives regularly calling on building owners and setting up attractive financial packages to encourage efficiency.

To some extent already, the utility industry has begun to capitalize on the natural market for energy services. One example is Puget Sound Power & Light's establishment of a subsidiary called Puget Energy Services. The subsidiary focuses directly on selling and marketing energy services for efficiency and load management. Its business includes leasing, renting, and financing energy-using equipment.

As Gellings points out, utilities have a natural entree to the energy services market through their already established customer base. They also may have the biggest stake in the use of energy-efficient technologies. According to EPRI's figures, the installation of one 10-ton commercial heat pump brings the manufacturer about $5000, the installer about $10,000, and the utility about $25,000 in electricity sales over the life of the equipment. But getting utilities to branch out into the business of energy services won't be easy. "Moving into a totally new business is difficult for anyone," Gellings says. "It requires a fundamental leap of faith."

Rosenfeld is confident that regulatory reforms will pave the utility industry's way into the energy services business. "The tables are really turning," he says. "And I think it's a permanent change. I think this is the beginning of a revolution in which 10 or 15 or 20 years from now, utilities will be different because they will be designed to sell the most valuable energy services rather than just electricity."

Electricity is key to efficiency

Whether or not the electric utility industry chooses to be the leader of today's energy efficiency movement, it is clear that electricity use will be crucial to that movement's success for the simple reason that it is the most efficient and versatile energy form available. In fact, replacing fossil fuel end-use technologies with efficient electric technologies, primarily in the industrial sector, would result in net savings of about 291 trillion Btu in 2000, according to EPRI's efficiency study. Even though an extra 32 billion kWh of electricity would be consumed, energy use would decrease 48%.

Some of the largest individual opportunities for savings are in the industrial sector. "In typical industrial applications, electricity-based processes are at least

The Push and Pull of Promotion

Manufacturers typically use two strategies in promoting improved products. With the "product push" approach, the producer aggressively promotes the product to the wholesaler, who then pushes the retailer to stock it for sale. With a "demand pull" strategy, the producer concentrates his marketing directly on the consumer, building up demand; the consumer then asks the retailer for the product, the retailer asks the wholesaler, and the wholesaler asks the producer. Utilities can participate in both strategies.

Product Push Strategy

Demand Pull Strategy

Utility Marketing Strategies

Utilities use a number of methods to market conservation and energy efficiency to their customers. The choice of methods for a particular program depends largely on the specific customer segment being targeted.

twice as efficient as their fossil fuel alternatives," says Yau. "That's even accounting for the 65% of energy typically lost in converting 'primary' energy into electricity." Often much fossil fuel energy is wasted in heating things other than the desired material—ambient air or a container, for example. Electricity—a refined energy form—offers better control, allowing users to focus energy exactly where they need it. But electricity offers other advantages too, like significant gains in productivity and product quality, which can help U.S. industry regain its competitive edge in global markets.

Electricity is also cleaner than fossil fuels, even when power plant emissions are taken into account. This is partly because some electricity sources, such as wind, hydro, geothermal, and nuclear power, release no emissions.

Among the electrotechnology applications already showing great promise in our industries today is infrared paint drying and curing. This process results in a longer-lasting, higher-quality finish on surfaces as varied as metal, wood, and fabric. Chrysler currently is using electric infrared technology to dry and cure paint on two of its luxury-model cars. The estimated energy cost: about 8¢ per car. Typically, such finishes are dried and cured in convection ovens, which use large volumes of gas-fired hot air. With the electric infrared process, energy radiates directly to the painted surface and isn't wasted on the ambient air. And because the drying process is much quicker, surface smoothness is improved. Another advantage over the conventional drying process is a substantial reduction in the volume of volatile organic compounds emitted by solvent-based paints. (These compounds can deteriorate the earth's protective ozone layer.) Payback for the electric infrared equipment is often less than one year.

Induction heating also has shown U.S. industry significant gains in energy efficiency and product quality. Traditionally, metal producers and fabricators have used gas-fired furnaces to heat metal prior to forming, rolling, or processing. But these furnaces waste much energy, as they heat not only the metal but the furnace interior, its walls, and the surrounding areas too. With induction heating, the metal to be heated is slipped inside a wire coil so that the coil wraps around it like a sleeve. The coil then is energized by an electric current, creating a magnetic field that directly heats the metal. At a metal shop at the Fitch Works of Houston, Pennsylvania, the induction heating process consumes from one-third to one-half less energy than the gas-fired process. (That's 300 to 400 kWh per ton, compared with 600 kWh per ton.) Induction heating also solves several quality problems, including "skin" defects that can result from direct contact with gas flames; cold spots; and excess scale formation, which is inevitable in the gas-fired process, since the metal surface is exposed to high temperatures for longer periods of time.

One final example of an efficient electric industrial process is freeze concentration. Freeze concentration is a technique used to separate components of mixtures and solutions. Used as a substitute for the heat-driven processes of distillation and evaporation, freeze concentration typically is at least three times as efficient. That's because it takes about 1000 Btu per pound to vaporize water, but only 144 Btu to freeze it. And because freeze concentration is a lower-temperature process, it produces a better-quality product. In fact, when reconstituted, the product should be virtually identical to the original. Freeze concentration can be used in a variety of applications, from food preparation to wastewater treatment. Already it is making significant gains in the petrochemical and food industries. One EPRI report estimates that the substitution of freeze concentration technology for evaporation and distillation in all feasible industrial cases could save the industries involved $5.5 billion annually in heat energy consumption. Electricity use in those industries would increase by 20 billion kWh per year, but overall energy consumption would be reduced threefold.

As these examples show, advanced electrotechnologies offer obvious benefits to utility customers and to society at large. But the question remains: How do we achieve widespread use of these technologies in the marketplace? EPRI today is working to help bridge this gap in the efficiency equation by collaborating with manufacturers to get more-efficient technologies on the market. But additional effort is needed from utilities themselves if this organized, versatile, and inherently efficient energy form is ever to begin to live up to its potential.

"If we truly want energy efficiency as a society, it has to be through electricity-based technologies," Gellings says. "And it's the electric utility industry that has the most to lose or gain in terms of whether electric appliances are used or not used. If the industry doesn't promote energy efficiency, then who will?" ■

Further reading

Efficient Electricity Use: Estimates of Maximum Energy Savings. Final report for RP2788, prepared by Barakat & Chamberlin, Inc. March 1990. EPRI CU-6746.

Utility Energy Strategies: The Role of Efficiency, Productivity, and Conservation. Final report for RP2982-5, prepared by Energetics, Inc. February 1989. EPRI CU-6272.

DSM Residential Customer Acceptance, Vols. 1 and 2. Final report for RP2548-1, prepared by Synergic Resources Corp., Heberlein & Baumgartner Research Services, and Battelle, Columbus Division. April 1988. EPRI EM-5766.

A Compendium of Utility-Sponsored Energy Efficiency Rebate Programs. Final report for RP2884-9, prepared by the Consumer Energy Council of America Research Foundation and the American Council for an Energy-Efficient Economy. December 1987. EPRI EM-5579.

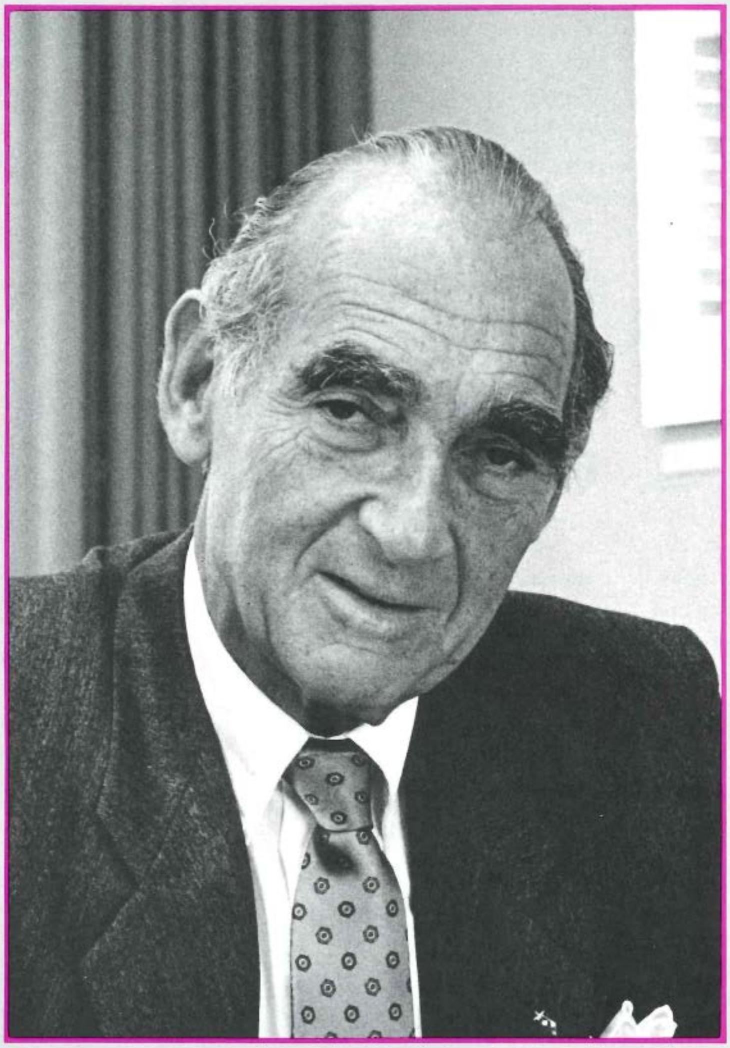
Moving Toward Integrated Resource Planning: Understanding the Theory and Practice of Least-Cost Planning and Demand-Side Management. Final report for RP2548-3, prepared by EPRI and Barakat, Howard & Chamberlin, Inc. February 1987. EPRI EM-5065.

Demand-Side Management, Vol. 3: *Technology Alternatives and Market Implementation Methods.* Final report for RP2381-4, prepared by Battelle, Columbus Division, and Synergic Resources Corp. December 1984. EPRI EA/EM-3597.

This article was written by Leslie Lamarre, science writer. Technical information was provided by Clark Gellings and Timothy Yau, Customer Systems Division.

HENRY LINDEN

Takes a Look at Electricity



The founding president of the Gas Research Institute is now an enthusiastic member of EPRI's Advisory Council. Linden's analysis of international development affirms electrification as a central force of economic and social progress in the modern world.

Electricity is really now the key to growth and development, both economic and social. Electrification is an economic imperative." These aren't the words you'd expect to hear from a chemical engineer who has worked for 42 years on behalf of the gas industry—31 with the Institute of Gas Technology and 13 (including a two-year overlap) with the Gas Research Institute, which he helped organize.

But Henry Linden speaks straightforwardly, even urgently, of the analytical work that underlies his conclusion. "The data are so convincing. Marginal electricity intensity values everywhere are so similar. A modern industrial economy requires somewhere between 1 and 2 kilowatthours per 1972 dollar of GNP growth. The Scandinavian countries use roughly twice as much because they're so heavily electrified, thanks to an abundance of cheap hydro power. But everybody else—the UK, West Germany, Japan, the United States, Italy, France—is in the same narrow range.

"That seems to be rather convincing," says Linden, his tentative phrasing contradicted by an increasingly insistent manner, "but the linearity of plots for even the developing nations is further evidence. The dependence of economic growth on electrification is *not* limited to industrialized countries."

After a moment's reflection, Linden adds, "My theme for years has been that the substitution of commercial energy forms and energy-intensive technologies for human and animal labor is at the root of economic and social progress. Clearly, electrification is simply the last stage of this process."

Such personal conviction often shows up in Linden's conversation, but most of his writing on the topic is tutorial, and academia is the umbrella over all his work. For more than 30 years, he was an adjunct or research professor of chemical engineering or a professor of gas engineering at the Illinois Institute of Technology (formerly the Armour Institute). IIT's Chicago campus is also the home of the Institute of Gas Technology and a number of other energy research, educational, and consulting activities. Since 1987 Linden has occupied a professorial chair in chemical engineering there, and during the 1988–1989 academic year he headed the department. Even more recently, last July, he became IIT's interim president and CEO—"my third not-for-profit presidency," he comments.

Since April 1987, Linden has served on EPRI's Advisory Council, along with some 20 others from a variety of positions in such fields as conservation, education, finance, law, manufacturing, publishing, research, and utility regulation. Individually and as a group, Council members offer representative outside opinions to EPRI management on societal trends that might shape utility industry R&D priorities and directions.

From Austria to America

A distinctly Viennese intonation still marks Henry Linden's deep, slow speech. There isn't a touch of Chicago—and certainly none of Georgia, where he went to school from 1939 to 1944, first in agriculture, then in textile engineering, and finally in chemical engineering at Georgia Tech. How he came there is a classic account of migration during the upheavals that led to World War II.

Vienna was Linden's boyhood home, where he grew up in a sophisticated, highly career-oriented family. "Both my grandfathers were research MDs," he explains, "and Vienna was a scientific and cultural center. My father had a doctor of civil law degree, but he made his living as an artist, as a portrait painter and teacher. He fought in World War I but was granted leave to paint a set of miniatures for the last Habsburgs. He also volunteered to fight the Bolsheviks in the aftermath of the war. My mother was a fashion editor."

The family was comfortable, and although one couldn't grow up in Central Europe without being aware of new war threats, the warnings weren't heeded. Finally, Linden says, "I remember going skiing with my class in 1938, when I was just 16—it must have been February—and a false report came over the radio that the Germans had marched in. Half my classmates pulled out swastika armbands and started to celebrate. When I got home, I tried to convince my parents that it might be a good idea to get out."

Within six months he was in Holland, and by the fall of 1939 the family was in the United States, settled on Long Island, where Linden's father again painted and taught, as many as 60 students much of the time. The move was permanent, the family knew it, and they all became U.S. citizens within a few years. "I was raised as an Anglophile, really," says Linden. "In Vienna I had already entered a technical secondary school, with the full intention of working in England as a textile engineer."

But at 17 in America Linden was still two years short of completing secondary school, and his interest was agriculture. He therefore hit upon West Georgia College, a junior college in the state university system. "It was in Carrollton. I remember trying to get a bus ticket from Atlanta, and because of my r's, they thought I was saying Covington!" Linden adds, however, that his English was good enough to make all A's. "I spent two absolutely fabulous years there. I worked on the school farm 20 hours a week. I learned to plow with a mule and a 'middlebuster' plow. I helped one of my instructors do an economic study of truck-farming operations outside Atlanta. And it was a coed school—I'd never seen such beautiful girls! I got acclimatized."

Linden transferred to Georgia Tech as a sophomore in the fall of 1941. Still a work-study student, he worked briefly for Georgia Power Co. "It was my first brush with electricity," he says with a chuckle. "I put advertisements in the Atlanta streetcars!" Agriculture had paled for Linden by then, and so had textile engineering. "The Georgia textile industry

"The substitution of energy-intensive technologies for human labor is at the root of economic and social progress. Electrification is simply the last stage of this process."

was paying work-study engineers 30¢ an hour, so I switched to a higher-priced profession, chemical engineering."

The reminiscence of how he decided to make energy his life's work is one of Linden's favorites. He clearly remembers the turning point, a course called Gas and Fuel. "I was fascinated by the correlations between the physical, chemical, and combustion properties of the various fossil fuels. And that was it. When I graduated in 1944, I went to work for Socony Vacuum—which later became Mobil—and I continued in that field."

Linden's work at Socony Vacuum focused on the combustion properties and gasification potential of petroleum fuels. He mined the same subject matter for his master's thesis at Brooklyn Polytechnic (now Polytechnic University), and he carried this developing expertise to Chicago in 1947 because he could study part-time toward his doctorate at IIT while working for the Institute of Gas Technology on the gasification of petroleum fractions. His career path was thus set: "I have been affiliated in some way with IIT ever since October 1947."

Career comes first

The Institute of Gas Technology, established in 1941, served until recently as IIT's department of gas engineering, but with a gas industry membership constituency (mostly pipeline companies and equipment suppliers) to support its scholarships and fellowships, draw on its continuing education programs, and fund basic research and information services. IGT performs research on its own, but mostly under contract for others, and Linden climbed all the way up its career ladder: oil gasification supervisor until 1952, assistant or associate research director until 1956, research director until 1961, institute director until 1974, and president until 1978.

In 1976, with EPRI as his model, Linden led the effort to organize the Gas Research Institute. Although headquartered on the IIT campus until 1981 for convenience, GRI had no affiliation there. It was—and is—an independent arm of the gas industry, charged with increasing the industry's level of cooperative R&D. Like EPRI, GRI would only plan, finance, and manage its program; the research would be performed by contractors. Of course, there have always been significant differences between GRI and EPRI, primarily because of the limited vertical integration of the gas industry, its unregulated production segment, and the control of GRI's funding (both its mechanism and level) and program by the Federal Energy Regulatory Commission.

Linden was the founding president of GRI, serving until three years ago, and is still an executive adviser. His career connections are orderly, linear, and narrow, focused mainly on gas, on technologies for its use as a primary energy source, and on the personal diplomacy that has built industrywide R&D support to a new high. However, he also is a director of six corporations, in businesses ranging from venture capital to aluminum production, and he takes satisfaction from applying what he has learned about management to his not-for-profit operations.

His professional interests in the energy field have also broadened to include sources and forms other than gas, and their implications for the U.S. and world economies. As he puts it, "I've done oil. I've done coal, oil shale, and synthetic fuels. I've certainly done gas, and even renewables. Now it's time to do electricity."

These career and professional interests are almost the extent of Linden's identity. They definitely fill his day, every day. He's an energetic, inquisitive, good-natured workaholic—and loves it. He laughs agreeably at the description and affirms it. "Clearly, I've always been totally career oriented."

But it would be wrong to conclude that Linden has no personal life. He simply doesn't compartmentalize it. He travels widely and frequently, warmly befriending people wherever he meets them, not distinguishing between industry and other acquaintances. And he hasn't lost his interest in agriculture; he has his own farm in Wisconsin.

Natalie Govedarica, Linden's wife, is an industrial engineer—an IIT alumna, he adds—and of Serbian origin. "She accuses me that my foreign travel is now limited to the confines of the old Austro-Hungarian Empire. I'm still rather Austrian, you know," he adds, referring pointedly to their lively exchanges on Central European and Balkan history. "To me, the empire seems to have been the most stable and benign political and economic system for the multinational Danube basin." In fact, since his first return to Europe in 1967, Linden and his wife have visited there often, sometimes skiing, sometimes searching out the summer camps, lakes, and spas where he and his parents had spent their month-long vacations before 1938.

With his marriage to Natalie in 1967, Linden's son and daughter (then 16 and 12) from a previous marriage had to make major adjustments. He speaks freely of their life and times together. "There were the ups and downs that you know about from anyone whose children were born in the early and middle fifties and who went through a divorce. But if you stick with them—really stick with them—they pull through just fine."

Linden says of himself, "I'm not much of a family man. I don't golf, and I don't travel around visiting children." Then, in the next breath, he speaks warmly of joining his daughter and her family for dinner only the night before. "She has always loved animals—became a veterinary technician and has done well." And he recounts that his son, at first a liberal arts graduate, later returned to school for a degree in chemical engineering and has just now been named to a vice presidency of a major gas pipeline company.

Elasticity in his thinking

Of his IIT association nowadays, Linden says, "The most fun I've had recently, just last year, was teaching a new course called The Role of Energy in Industrial Economies. It really wrapped up everything I've learned over the years." It also is the platform for much of what Linden writes these days and for what he calls "a major change in my understanding of the energy-economic system." He has gone, he says, "from one motivated to look for shortages of natural resources to one who absolutely no longer believes in them."

For support, Linden turns to the record of geologists, who have many times been wrong—"always wrong," he interjects—in their estimates of remaining world oil and gas supplies. Predictions that we will soon run out of these resources have repeatedly been countered, Linden asserts, by new discoveries whenever prices rise high enough to stimulate more-aggressive exploration and development. High prices also depress demand, thus extending reserve lifetime.

Does this mean that he has become an economist, relying on price elasticity? No, because there's more to it than that. "Economists don't understand technology elasticity," Linden says. "My contribution to the literature, and to teaching and policymaking, is that price elasticity and technology elasticity together give us a tremendous range of opportunity to avoid any crisis that can be called the result of a shortage."

Technology elasticity in this context, says Linden, means the capability of expanded or advanced practices to lengthen the economic life of a resource—by discovering more of it, making it more accessible, or using it more efficiently. Discovery enables us to breathe more easily about the future; accessibility adds to proved reserves, defined as the portion of a resource that is economically and technically recoverable today; more-efficient resource use—the result of technology advancement—also enlarges proved reserves by raising the acceptable unit-price level.

Linden explains with an example. "The consensus number for the recoverable natural gas resources in the lower 48 states is some 600 TCF—600 trillion cubic feet—if we assume wellhead costs no greater than $3–4 per million Btu and continued technology advances. At current production rates that's a 35-year supply. (I'm discounting Alaska because its resource isn't really commercial.) But all this is constantly being expanded by technology that teaches us to find gas where we haven't found it before."

"I've gone through a major change in my understanding of the energy-economic system, from one motivated to look for shortages of natural resources to one who absolutely no longer believes in them."

About economic access he says, "There is natural gas in tight formations and also in deep or thin coal seams that can't be mined. It had been considered irrelevant. But GRI research has given us an understanding of how to recover that gas economically, by reservoir fracturing and other enhanced production techniques. In this way we've added something like 200 TCF to the supply base."

There's significance for electric utilities in what Linden is saying. "Many of my peers feel that the use of natural gas to produce electricity at some points in the system is, perhaps, its highest-value use." He cites cogeneration and combined-cycle power generation as big growth markets for natural gas. Combined cycles (in which combustion turbine exhaust is used to vaporize water for a steam turbine) are relatively low in first cost. They're also so fuel-efficient that the break-even gas price can be as high as $4.50 per million Btu for a baseload plant, according to Linden, and more than $6 for an intermediate plant. "That's pretty good," he exclaims; "$4.50 at the burner tip corresponds to a wellhead price of $3 or $4, which is substantially above the current spot market, or even the long-term contract price, for a lot of gas today."

Linden's conversion from his former "ready acceptance of energy security and shortage philosophies" dates back to the mid-1970s, when he was involved in what he flatly describes as multibillion-dollar failures—the synthetic fuels program was one—for a motivation that has since troubled him. "It was in the self-interest of the technological community to accept those programs because they generated a lot of research funding and jobs."

Hard words from an acknowledged leader of the R&D establishment. Is there a solution? "Sort out your self-interests, consciously," Linden insists. "Declare your biases up front, the way you do for the National Research Council. When you're in an advisory capacity," he concludes, "intellectual disclosure is much more important than financial disclosure."

Guiding collaborative research

GRI was born in a time of perceived resource shortage, Linden recalls, and its first five-year research plan was very heavily oriented toward coal gasification, conversion of oil shale to natural gas, and other gas substitutes. "Sure, there was a shortage," he says with an ironic chuckle. "It was a shortage of gas controlled at wellhead prices below the marginal cost of finding more. When it costs a dollar to find and produce it and the regulated price is 50¢, you're going to have a shortage—of 50¢ gas!"

Within a year or two, however, when he realized the resource base was there, Linden virtually turned GRI around. The Natural Gas Policy Act of 1978 added impetus. Prices thereafter started moving up, as rapidly as 20% annually, and the gas industry had to do something to stay competitive. For GRI, says Linden, "it became obvious that the cost-effective response was to make end-use efficiency improvements."

The move was a success, as Linden illustrates. "Gas furnaces were the bulk of the problem—a lot of them were only 55% efficient, and gas heat was being installed in only 33% of new single-family homes. So we started with the residential market, although we also went into commercial and industrial applications and cogeneration too. The pulse furnace was a breakthrough—combustion in short, efficient bursts. Gas heat use in new houses is now back up above 50%. There are gas heat pumps too, and gas cooling is threatening electricity's monopoly."

This talk of GRI's transition prompts Linden to observe that EPRI, serving a vertically integrated industry, has remained primarily concerned with the technologies and economics of generation, transmission, and distribution because that's where the power industry's investment is. EPRI's end-use R&D has come into prominence more recently. "We are moving closer together," Linden says.

"The function of government is to ensure a stable supply of essentials. The ancient Egyptians stored grain during periods of surplus. I think energy has a comparable position today—requiring subsidization during a period of restructuring to meet environmental realities."

"Also, GRI is investing more in gas operations—storage, transmission, distribution, and safety," he adds. "And it's on a kick of increased supply research and looking for new, least-cost applications for gas. Two obvious ones are distributed power generation and commercial cooling." Those same applications draw EPRI's interest, he notes.

Thus, despite the regulatory and other distinctions between the gas and electricity industries, the paths and problems of their collaborative research institutions have many parallels. Because of Linden's instrumental role at GRI, he was in many joint meetings with EPRI senior management over the years, and EPRI therefore invited him to Advisory Council membership—after he stepped down from his GRI post, of course. "I've become an electricity enthusiast," he admits.

Linden frankly emphasizes the opportunity to learn as well as to advise. "The presentations by EPRI senior staff are excellent. George Hidy's analysis of global warming went back to the ice ages, so I got the visuals and used them for a lecture in my course.

"Learning also comes from exchanges with other Council members," he goes on. "When it comes to end-use R&D, I give more than I get, because I was a specialist in the field myself. But when it comes to nuclear power, I don't teach; I learn."

Linden's examples show that the individual expertise of Council members is valuable. "But there's one important consensus," he insists. "When the seven regulatory commissioners on the Council agree on something, you'd better listen. They are the critical link in the chain of cooperative R&D funding for the electric utility industry. It isn't that they're right or wrong on technology, necessarily, but that they understand public attitudes—environmentalists, governors, attorneys general, League of Women Voters, everybody."

Advisory issues

According to Linden, however, there are some energy policy areas where technology produces subtle economic ramifications that are difficult for anyone to sort out. Least-cost energy service is a concept that illustrates his point. "Everything that GRI invests in," he says, "must conform to the least-cost strategy for the gas user. With everything rolled in, it must be predictably cheaper over its economic life than any other energy option."

But Linden believes the concept has been oversimplified, even misused, by state and federal regulatory bodies, who have neglected such values as energy security and quality. "There has to be equivalent quality of service," he explains. "It isn't sufficient to favor the bare-bones energy cost alone.

"In a manufacturing application, for example, when you consider the productivity of the equipment investment—the product rejection rate, the labor intensity, the load factor, the on-stream time you can maintain between overhauls—it may happen that 6¢-a-kilowatthour electricity, which is $18 per million Btu, is cheaper than gas at $2 per million Btu." In summary, he says, all costs must be internalized—"everything, including environmental costs."

The viewpoint sounds right enough, logical and rational, but idealistic in a time of continuing popular and congressional controversy over pollution cleanup and waste storage costs, which are subsidized any time tax money is allocated for the purpose. Furthermore, if Linden believes such costs should be internalized, how can he speak and write, as he has, on behalf of R&D subsidies?

The answer comes quickly. "I'm not speaking in favor of government subsidies. I'm speaking in favor of regulated industries—utilities, which have no upside earning potential—being able to organize cooperative R&D programs, with the costs passed on to the ultimate beneficiaries, namely, the customers of those utilities."

But Linden doesn't duck the issue of what he calls accumulated environmental debits. The shareholders and customers of an industry shouldn't be stuck with the cost of a societal departure from prior law, he says. "When government decrees that the environment should be corrected, there certainly seems to be a taxpayer responsibility." He sees parallels in historical subsidies of agriculture, transportation systems, and telecommunications. "The basis of civilization, really, the function of government, is to ensure a stable supply of essentials. The ancient Egyptians stored grain during periods of surplus. I think energy has a comparable position today—requiring subsidization during a period of restructuring to meet newly realized environmental realities."

As a prolific speaker and writer on a wide range of energy policy matters, Linden has many opportunities to be provocative. For example, he says in passing that institutional R&D is often irrelevant. The problem is largely one of research goals, he explains—how specific and how soon. "There's no excuse for always saying that results are five years off. That's what has given institutional R&D a bad name—that and its reputation for scoffing at definable economic benefit," he asserts. "It's not that we're short of things to research and develop. Why not concentrate on things that have a reasonable payback?"

Most of an institutional R&D budget should be tightly defined in terms of program content and economic benefit. "But you should always set aside a reasonable percentage for exploratory research," Linden says. "At GRI the figure is 13%, and even that is mission oriented." Speaking of EPRI's R&D program, he adds, "You know, 10 or 15% of $350 million is a lot of money. True innovation doesn't require a lot. Just think, if you hit with something truly innovative—say, cold fusion!"

Transcendent energy role

It's a long way from Linden's Austrian boyhood, through the cataclysm that uprooted his entire generation in Europe, to his respected status today as a senior spokesman in the U.S. energy community. Linden is fatalistic—his word—about the events that launched him westward, but he is pointedly aware of choosing to be a part of U.S. society.

"Environmentalism has done a super job of alerting us to a number of clear dangers, but when I hear it used to justify a no-growth philosophy—well, I know the industrialized world isn't willing to settle for lower standards while technological fixes are available."

"Right now, there must be at least a billion people in the world who would love to become American citizens," he says. "The desire is widespread; it's a long tradition, a holy grail. To have an American passport, to become an American citizen, has incalculable value. This country, this culture, is one of the world's few islands of political stability and relative social tranquility, yet with tremendous constructive ferment and unabated optimism for the future."

As such, he says, the United States has a very important role, which must not be weakened by inappropriate ideological agendas—including those that may arise through science and technology. For example, Linden asserts, "environmentalism has done a super job of alerting us to a number of clear dangers, but when I hear it used to justify a no-growth philosophy—well, I know the industrialized world isn't willing to settle for lower standards while technological fixes are available. And the undeveloped world—even the developing world—needs all the growth it can finance, just for survival."

The energy-economic connections are clear and inescapable. But Linden sees a further, transcending implication of energy. "You can't have political freedom without physical mobility," he states. "If you don't like it in one part of the country or in a given nation, the fact that you can move yourself physically is important. We're seeing how this works right now, in Eastern Europe." Energy is also a means of social and economic mobility—perhaps not the only one but the most evident. For Henry Linden, clearly, advances in the human condition are inseparable from advances in energy technology. ■

This article was written by Ralph Whitaker from an interview with Henry Linden.


CQ Inc.
NOW
OPEN
for
BUSINESS

EPRI's Coal Quality Development Center, which for eight years has performed research and development aimed at helping utilities burn coal more cleanly and economically, is entering the 1990s with an expanded mission. This spring, the facility begins operation as part of EPRI's first subsidiary—CQ Inc.—which will continue the work of the center while operating as a for-profit business performing proprietary work for coal companies, equipment manufacturers, and government agencies.

By spinning off the facility, EPRI management intends to keep the center available to member utilities beyond 1991, when it would have successfully completed its 10-year R&D mission and faced a shutdown. The formation of CQ Inc. will preserve the unique facilities of the Coal Quality Development Center and the expertise of its staff at a much lower cost to EPRI. In addition, opening the CQDC to a broader client base will benefit EPRI members indirectly in ways that were not previously possible.

"This initiative should result in a greater investment in coal quality research and development that will directly benefit utilities," says Clark Harrison, president of the new subsidiary. "CQ Inc. will continue to serve EPRI and its member utilities while making the services of the Coal Quality Development Center available to a broader range of customers. This will strengthen our capability to serve EPRI and its members."

Kurt Yeager, vice president of EPRI's Generation and Storage Division, provides a further perspective. "The conversion of the CQDC into a for-profit EPRI subsidiary reflects an innovative prototype for the management of EPRI test facilities that relies on the market to determine continuing value," he says. "It also encourages these facilities to work as closely as possible with their utility customers in transferring that value without draining EPRI's limited R&D resources in the process."

THE STORY IN BRIEF

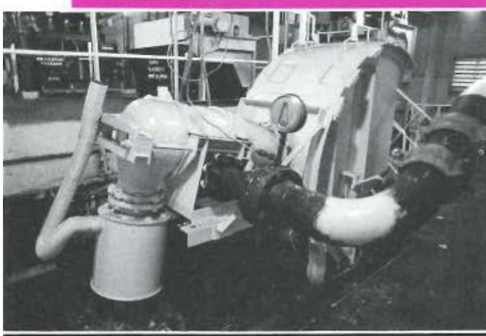
In the eighties, EPRI's Coal Quality Development Center pursued a program of research matched nowhere else in the world—developing advanced coal-cleaning techniques and specifying the best way to prepare specific types of coal to improve power plant performance and reduce emissions. Today, as the CQDC nears the end of its 10-year charter, the Institute is extending the facility's use by spinning it off as a profit-making subsidiary, newly designated CQ Inc. The facility's client base will be broadened to allow coal companies, equipment manufacturers, and other organizations to benefit from the center's unique capabilities. Its work will take on a more service-based focus, including troubleshooting problems at coal-cleaning facilities and power plants, testing cleaning and handling equipment, and helping utilities determine the extent to which cleaning, blending, and switching can satisfy emission limits.

Unique Facility, Expert Staff

Coal can be cleaned in a multitude of ways with CQ Inc.'s battery of cleaning processes. Equipment can be arranged in various configurations to produce over 50 cleaning sequences, allowing the staff to determine the most cost-effective cleaning method for a particular coal.

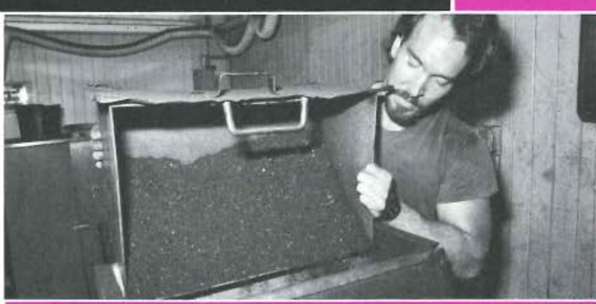
Concentrating table

Checking a sampler test device

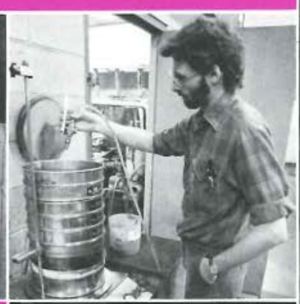


Heavy media cyclone

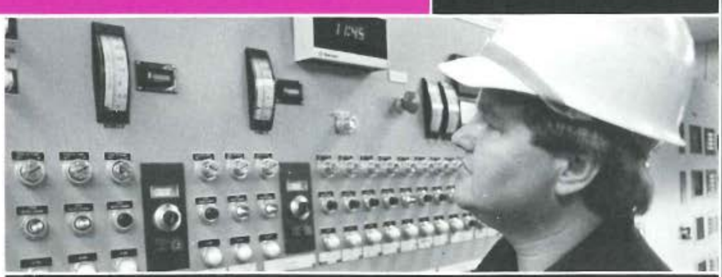
Flotation



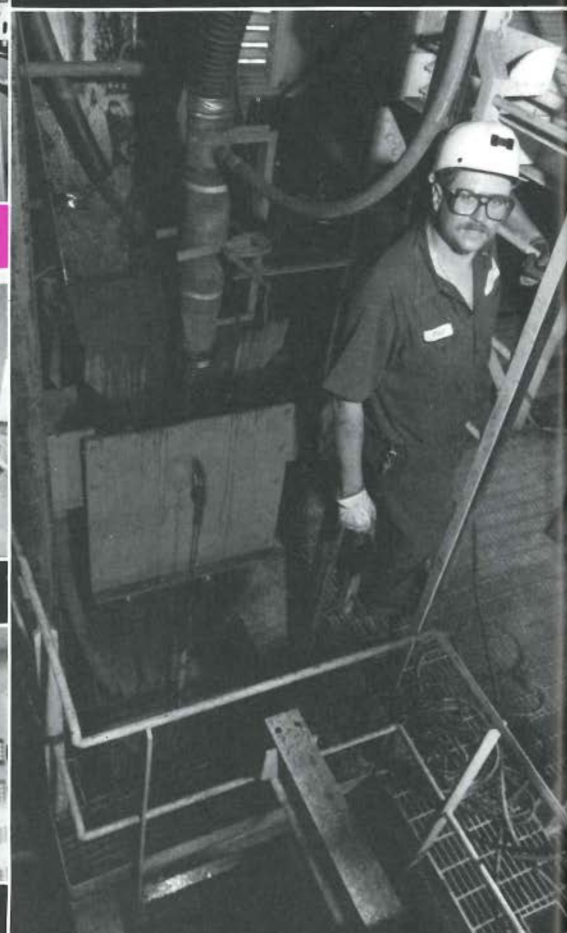
Coal sample splitter



Coal size analysis

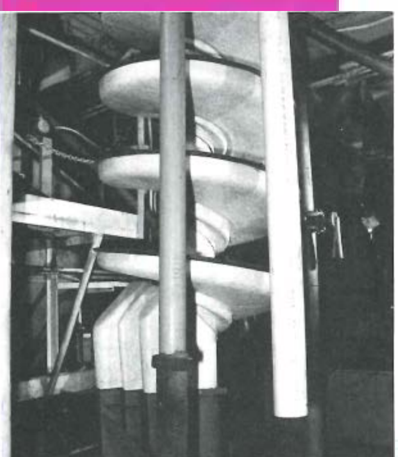


Control panel



EPRI Moorhead sieve

rry sampler



ral classifier

h flotation

A unique facility

The Coal Quality Development Center is one of several EPRI-operated facilities that develop, test, and improve key near-term technologies and demonstrate them on a commercial scale. Such facilities are intended to bridge the gap between research and real-world application, and EPRI establishes them in cases where there are no other facilities capable of doing the work. The Coal Quality Development Center is unique, being the world's only commercial-scale coal-cleaning R&D facility. The center was established in 1981 on a 50-acre site near Homer City, Pennsylvania, that is leased from Pennsylvania Electric and New York State Electric and Gas. In 1982, the center embarked on a 10-year mission—"to research, develop, and demonstrate ways utilities can reduce the cost of generating electricity, increase the efficiency of coal-fired power plants, and reduce emissions by improving coal quality." To do this, the CQDC staff has taken a three-pronged approach: evaluating processes for removing impurities from coal before it's burned in utility boilers; characterizing the cleanability of major U.S. coals for a coal quality database; and developing and demonstrating new techniques for improving coal handling, sampling, weighing, and analysis. The project's total authorized EPRI funding through 1991 is $54.5 million, with outside cofunding providing an additional $11.1 million.

The facility is unmatched because of its flexibility. Different types of commercial cleaning equipment can be hooked up in various configurations to simulate more than 50 cleaning sequences, or flowsheets, enabling the center's staff to conduct an array of tests on a particular type of coal to determine the best cleaning method for it. Since the center's equipment is of commercial size, such tests are more applicable to the real world than those performed in a laboratory under carefully controlled conditions. In contrast to laboratory tests that use small samples of coal, the CQDC's coal characterization tests are conducted on 500- to 1000-ton samples donated by utilities, coal companies, and other organizations concerned with the impact of coal quality on their operations. The same commercial-scale equipment can also be used to produce high-quality customized coal and coal-water slurry for other research and demonstration purposes.

The center has characterized the properties and cleaning potential of some 30 types of coal and compiled this knowledge into a computerized database, the Coal Quality Information System. In addition, the CQDC has studied the effects of burning specific coals in utility boilers; developed guidelines for coal cleaning, sampling, screening, and analysis; and demonstrated improved techniques for removing moisture from coal. By applying the results of research performed at the center, EPRI member utilities have documented savings of more than $200 million.

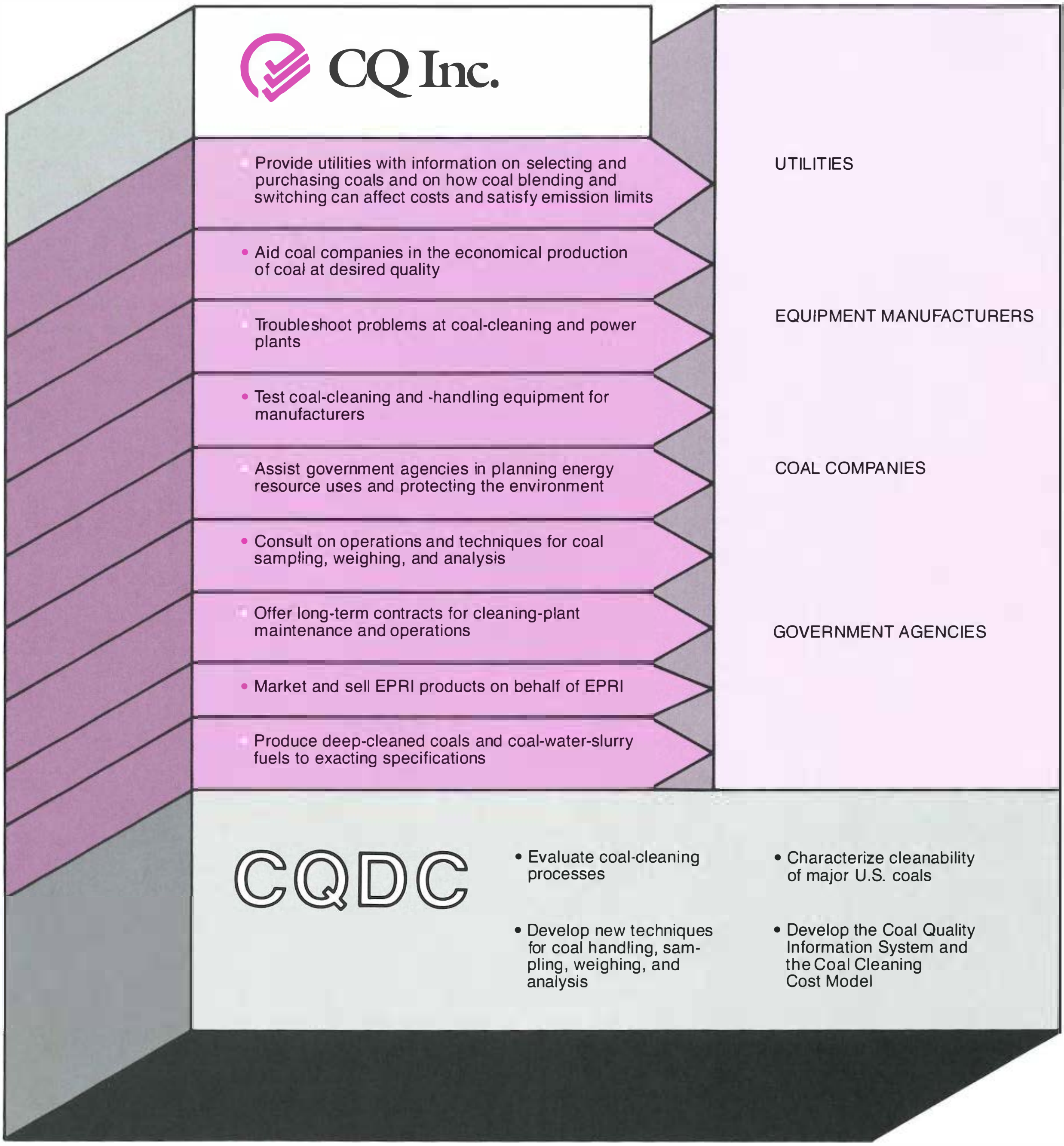
Avoiding a shutdown

In 1988, 7 years into its 10-year mission, the CQDC came to a crossroads. "EPRI's policy is not to build or maintain its own R&D facilities unless there is no other reasonable way to satisfy the technical needs of our members," says Alex Fremling, EPRI's corporate secretary and deputy director of the Business Management Group. "We have such facilities by exception, and the exceptions are approved by the Board of Directors." To ensure that its outside R&D facilities make the best use of its members' dollars, the Institute periodically conducts a sunset review procedure established by the utilities represented on EPRI's Research Advisory Committee. In each case, a review is performed to critically examine a given facility's progress in meeting its goals and to determine whether sufficient need exists to warrant its continued operation.

Explains George Preston, director of the Fossil Power Plants Department, "The procedure calls for a formal review at least every five years of every major facil-

New Business Directions

Building on the foundation of research and development established by the Coal Quality Development Center, CQ Inc. aims to offer a variety of services to a broad client base.



ity we have—a review of its original objectives. We ask whether those objectives are still valid, what the options are for meeting them, and whether the current facility remains the best option for meeting them. If all of those answers are positive, we may choose to keep operating the facility. If not, we may want to accomplish the objectives in some other way. We're not here to establish facilities that go on and on and have a life of their own."

The 1988 sunset review of the CQDC concluded that the center's progress was on track and delivering value to EPRI members, and that there was a continuing need to operate the center through the remaining three years of its mission. But then what?

By 1991 the center would have successfully fulfilled its original charter, and its portion of EPRI's budget was slated to be diverted to other critical R&D projects after that time. Having in large measure served its purpose, the CQDC was to be shut down unless the Institute could develop some strategy to support its operating costs. "EPRI's premise when it was formed was to leverage its members' dollars by not creating permanent R&D facilities," says George Touchton, program manager for fossil plant operations. "But when we began to talk about shutting down the Coal Quality Development Center, we were reminded that we had unique R&D capabilities there that were still of great potential benefit to our members, but that could not fully justify the continued operating and support costs of a wholly owned facility that is captive to our research program."

There were compelling reasons for preserving the unmatched capabilities of the CQDC in order to serve the interests of the industry and the nation as a whole. The biggest reason was coal's center-stage position in the nation's energy picture, which is affected by the mounting challenges confronting coal-burning utilities. Low-cost electricity from coal is firmly bound to the nation's continued economic strength and competitive standing in the global marketplace. Coal-fired power plants generate more than half of the electric power in the United States. Besides having the lowest price per unit of energy value of all fossil fuels, coal is an abundant domestic resource that is not subject to geopolitical upheavals.

But the physical and chemical makeup of coal poses special challenges for generating power in an environmentally sound manner. Although great strides have been made to lessen coal's environmental impact, the utility industry is facing new legislation that could impose further reductions on emissions from coal-fired plants. To comply with the new requirements in a cost-effective manner, utilities have to make informed decisions on how coal cleaning, blending, and switching compare with scrubbing and other control technologies for meeting the new emission limits.

The composition of the coal burned in a utility boiler affects not only emission levels but also virtually every aspect of a power plant's operation. Most plants were designed to operate with a fairly narrow range of coals; burning coals outside this range—either to reduce fuel costs or to satisfy emission limits—could lead to expensive problems, including higher maintenance costs, forced outages, and derating. Information on such impacts allows utilities to make a choice that's based not just on the cost of coal as delivered, but on the cost of the coal per kilowatthour delivered to the customer—a more realistic bottom line.

This issue is becoming even more important as the industry becomes increasingly market driven. Utilities are encountering growing competition from independent power producers as well as from each other, while facing pressure from regulatory commissions and customers to stabilize or reduce rates. It all adds up to a tough balancing act for coal-burning utilities, which must strive to simultaneously reduce emissions, control costs, maintain their productivity and competitive standing, and meet the need for new capacity. Helping coal-burning utilities meet these challenges has been the mission of the CQDC.

"Fuel represents more than half the cost of producing electricity at a coal-fired power plant," says Clark Harrison, "so whatever you can do to economize on fuel makes you more competitive. Buying the coal of economic choice will have an effect on emissions; it will also affect plant performance, maintenance costs, transportation costs, and ultimately busbar costs of electricity. Utilities have told us that they will be paying even more attention in the future to the fuels they burn, so we felt we needed to keep this facility to help them."

During the 1988 sunset review, the Generation and Storage Division's utility advisers urged EPRI to explore ways to keep the center's facilities and the expertise of its staff available beyond 1991 at a diminished level of Institute funding. Several possible courses of action were considered for prolonging the life of the CQDC. These included spinning off the center as either a not-for-profit or a for-profit EPRI subsidiary; another possibility was to preserve the status quo and continue to fund the center at past levels. EPRI formed an independent review group headed up by Alex Fremling, which evaluated the options in depth.

A creative initiative

As the review group evaluated the alternatives for prolonging the life of the CQDC, it became clear that expanding the center's client base could provide the necessary financial support. Although coal companies and other organizations with a stake in coal have paid to use the center and its research results, there has been a barrier preventing more of this nonutility business from coming in. That barrier is EPRI's status as a tax-exempt, not-for-profit research institute, which requires that the results of its research be made available to the public at large. The center's inability to perform proprietary work served to dampen the interest of coal companies and other potential clients, who for competitive reasons may want such information to be kept confidential.

The ability to perform proprietary research emerged as a central issue that shaped the review group's evaluation. After scrutinizing the alternatives, the group concluded that the best option was to establish a wholly owned, for-profit subsidiary to run the CQDC. This approach provided distinct advantages to EPRI and its member utilities. Most important, says Fremling, "the new organization will be able to more effectively seek work in areas where it is important to protect the proprietary information of its customers." In addition, the subsidiary, unlike EPRI, will work directly for the Department of Energy and other government agencies.

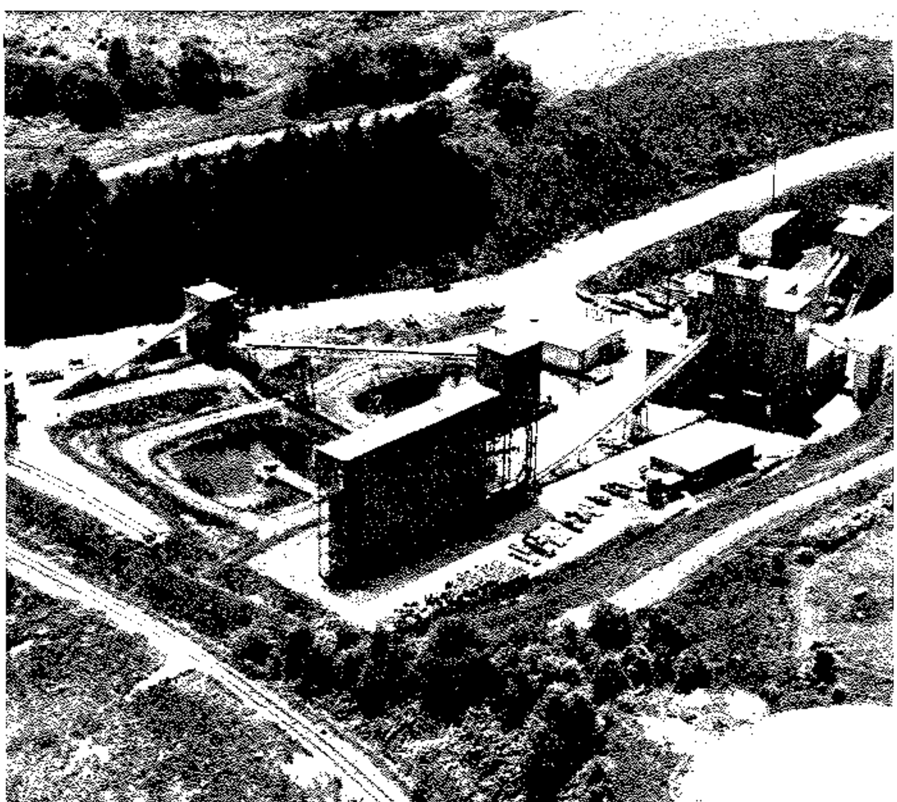
In this way, CQ Inc. provides another path by which member utilities can continue to get a return on the money they've invested in the CQDC to date, according to Preston. "Up to now that path has been closed because we haven't been able to do proprietary work. A potential client—for example, a coal company, a railroad, or a steel manufacturer—that wanted to use our capabilities to help determine the characteristics of a particular coal couldn't expect to keep the results confidential. And in that case the client probably decided not to have the work done. Our being able to do proprietary work under the new organization makes it much more attractive for these customers to use the facility." The competitive edge a CQ Inc. customer gains will in turn work to the advantage of utilities, Preston points out. "If a coal company can use CQ Inc. results to become more competitive, then utilities should see the effects in a lower-priced or better-quality coal."

The new organization's structure and business implementation plan took shape during the second half of 1989. EPRI owns all CQ Inc. stock and in exchange will transfer to the subsidiary the facilities of the CQDC. The subsidiary's board of directors is chaired by Kurt Yeager, vice president of EPRI's Generation and Storage Division, and includes EPRI's Alex Fremling and George Preston, CQ Inc.'s Clark Harrison, and Gary Brandenberger of Duquesne Light, representing EPRI's advisory committees. The new company's own business advisory council will include 6 to 10 people representing coal companies, equipment manufacturers, railroads, and utilities, who will provide customer perspectives on business and technology issues.

CQ Inc.'s business activities will build and expand upon the services offered by the CQDC. In addition to providing utilities with information on how coal blending and switching can affect costs and satisfy emission limits, the subsidiary will troubleshoot problems at coal-cleaning and power plants; test coal-cleaning and -handling equipment for manufacturers; consult on techniques for coal sampling, weighing, and analysis; and offer long-term cleaning-plant maintenance and operations contracts. In addition to performing R&D, CQ Inc. can support the work of others by producing deep-cleaned coals and coal-water-slurry fuels to exacting specifications. In selected situations, CQ Inc. will also market and sell EPRI products on behalf of EPRI.

EPRI members participating in EPRI projects will be able to continue to use the facility free of charge, says Harrison. When using the facility for independent work, members will pay established rates, as in the past.

Is the idea of a for-profit subsidiary inconsistent with EPRI's not-for-profit status? Not at all, explains Fremling; in fact, there's ample precedent for such arrangements. "Not-for-profit, tax-exempt organizations do this all the time. The subsidiaries pay taxes and conform to other legal requirements, and as long as the



subsidiary does not become the primary activity of the parent organization, it's quite appropriate."

It also makes good sense, both for the Institute and for its members, according to Preston. "Establishing CQ Inc. opens up the capabilities of an EPRI-developed facility to a broader range of clients in a way that protects the interests of the EPRI members who paid to establish the facility," he says.

Forming CQ Inc. as a for-profit business reflects the changing climate in the electric utility industry, Preston says. "Some utilities have nonregulated subsidiaries that could benefit from the results of EPRI coal quality research, but they're not entitled to get them because they aren't providing EPRI revenues. And in some cases, regulated utilities who are paying EPRI dues may not be in a very good position to use the results. The existence of CQ Inc. will allow those nonregulated subsidiaries to use the capabilities of the CQDC and the results of our past and future research programs, while sharing in the costs of operating the facility."

Building on accomplishments

Promoting synergy among the various organizations involved in producing, cleaning, and using coal was part of the motivation for establishing the CQDC in 1981, and this focus will continue as CQ Inc. builds on past accomplishments and broadens its activities. The company's near-term goals are to complete the original 10-year mission of the CQDC through contracted EPRI research projects and to transfer this information through EPRI to the membership. Beyond that, according to Harrison, the company aims to use the knowledge obtained over the past eight years under an overall strategic plan of industry needs. This intent is reflected in CQ Inc.'s midterm goals, which include providing comprehensive information to help utilities in selecting and purchasing coals, aiding the coal industry in the economical production of coal at desired quality, and assisting government agencies in planning uses of energy resources and protecting the environment.

Synergy and the focused application of acquired knowledge are reflected in one of CQ Inc.'s first projects with the U.S. Department of Energy. Teamed with Combustion Engineering, the company will develop a coal quality expert system under round 1 of DOE's Clean Coal Technology Program. Running on a desktop personal computer, the Coal Quality Expert (CQE) will allow utilities to purchase the lowest-cost coals tailored to their specific requirements. The system integrates several EPRI software products, including the Coal Quality Information System and the Coal Cleaning Cost Model, developed at the CQDC, and the Coal Quality Impact Model, developed by Black & Veatch under EPRI sponsorship. The idea is to enable a utility to determine and compare the total costs of generating electricity with alternative coals, factoring in the price of the coal as delivered, the costs of cleaning it, and its impact on the plant's operating and maintenance costs.

CQ Inc. will serve as EPRI's agent in licensing and commercializing the Coal Quality Expert. Under the terms of the Clean Coal Technology Program, DOE requires recoupment of government funds from the proceeds of commercial sales of the technologies developed. When the Coal Quality Expert is distributed to organizations that aren't EPRI members, CQ Inc. will collect the licensing fees and pay royalties to DOE. When the system is distributed to EPRI members, the licensing fees will be credited as being prepaid by virtue of EPRI membership.

"The Coal Quality Expert will provide an integrated perspective on all aspects of using coal," says Harrison. "It will allow us to view coal use in the full context of fuel supply, environmental controls, combustion, and power plant performance—all toward the overall goals of reducing emissions and lowering busbar costs. The development of that perspective is an accomplishment in itself, and being able to communicate that perspective to our members, to DOE, and to environmental groups reflects the technology and know-how that we've developed here over the past eight years."

CQ Inc. will also be completing work on EPRI-sponsored projects that were part of the CQDC's original mission. One of these is to develop an index to predict coal handleability—essentially, how well a coal moves through a power plant as a result of such physical characteristics as its moisture content, cohesiveness, and granularity. "The coal-handling systems in power plants are designed to handle coals with certain characteristics," says Harrison, "and utilities have various ways of specifying coals to be sure that they will flow smoothly through their systems. But none of those have been very reliable, so if they have to change to a different coal their systems may not be able to accommodate it." Substitution can result in costly problems, such as frozen coal and plugged chutes. "The idea," explains Harrison, "is to develop statistical and empirical relationships between coal characteristics and handleability and then develop an index that enables a utility to determine whether a given coal will be compatible with its systems."

For coal to achieve its full potential as an economical and environmentally safe fuel for power generation, the various organizations involved in its production and use will have to work in a complementary fashion. By taking a creative initiative to preserve the unmatched facility and staff of the Coal Quality Development Center, EPRI has taken a step that transfers the facility's overhead costs to the organizations that will most benefit from its continued existence, while increasing the availability of past coal quality R&D results to utilities to help them meet their economic and environmental goals. ■

This article was written by David Boutacoff. Background information was provided by Kurt Yeager, George Preston, and George Touchton, Generation and Storage Division; Alex Fremling, Business Management Group; and Clark Harrison, CQ Inc.

TECH TRANSFER NEWS

Robot Hands Royalty Check to Developers

The largest single royalty payment in EPRI's history underscores a secondary value that can flow from technology transfer. CECIL the robot, initially cosponsored by Con Edison, ESEERCO, and EPRI, first demonstrated its talents a little over two years ago, inspecting and hydraulically removing sludge deposits on the secondary side of a PWR steam generator at Con Edison's Indian Point-2.

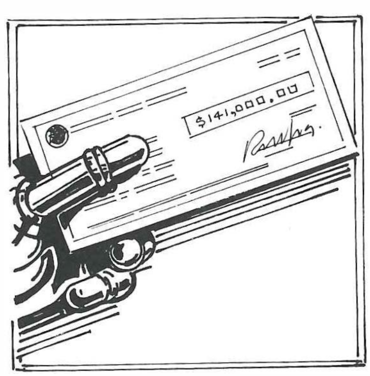
In January of this year, the manufacture and overseas sale of an upgraded CECIL system by Foster-Miller, EPRI's contractor for the original development effort, yielded a royalty payment of nearly $141,000 to EPRI and a now-larger group of cosponsors.

CECIL, which stands for Consolidated Edison Combined Inspection and Lancing, is a teleoperated machine designed to go after the sludge that accumulates in the dense forest of a nuclear steam generator's heat exchanger tubes. Up to a foot deep, the sludge inhibits heat transfer, and its voids become pockets of corrosion. The thousands of tubes, clearances of less than a third of an inch, and radiation levels all conspire against maintenance workers equipped with hoses and long, angled nozzles.

The remote-controlled CECIL today is a small cylinder about 18 inches long, suspended like a monorail car from a slender channel member—the combination shallow enough to be inserted through a 6-inch inspection port above the steam generator tubesheet. The self-propelled cylinder has an articulated belt, called a flex-lance, that can be thrust sideways between rows of steam generator tubes. Conduits in the flex-lance carry high-pressure water, electricity for a tiny TV camera and its lighting, and even a flow of nitrogen to clean the camera lens.

By rotating the cylinder as much as 180 degrees, CECIL's operator can direct the flex-lance to the right or to the left—and downward at any angle. Then, when CECIL moves along the "blowdown lane" (a straight passage across the steam generator between the tube bundles), its progress is measured by sensors that tell the operator where it is at all times.

In contrast to the image of research as a slow, methodical endeavor, the CECIL development project has been a fast mover. After surveying utility industry practices for removing sludge, EPRI began working



with Foster-Miller late in 1986, and the first workable prototype, CECIL-3, was delivered the following October for field trials at Con Edison's Indian Point-2.

The robot was a thorough success at inspecting steam generator sludge accumulations, a qualified success at removing them because some sludge deposits harden almost to the consistency of concrete. Attacking them effectively was difficult because CECIL-3 crawled along the blowdown pipe, practically at the same level as much of the sludge.

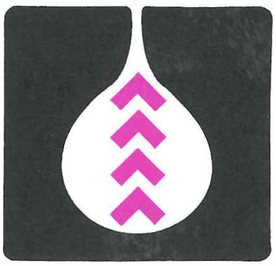
Since 1987, cosponsors Con Edison and ESEERCO have been joined by Public Service Electric & Gas and Northern States Power. Together, they have worked with Foster-Miller to refine the CECIL design, improving its speed and control, elevating its travel path above the sludge for better access to it, and tripling the hydraulic pressure from 2500 to 7500 psi. All the cosponsors have now put CECIL-4 to work in steam generators of their own, and all of them share the licensing royalties pro rata. ■ *EPRI Contact: C. Lamar Williams, (415) 855-2789*

Research Revalidates Steam Cycle Additive

Duquesne Light used morpholine as a pH and corrosion control agent at two fossil fuel power plants back in 1955. It tested morpholine in 1963 at Shippingport, the nation's first commercial nuclear demonstration plant, and adopted morpholine there in 1971 as part of an all-volatile treatment (AVT) scheme for water chemistry control.

Finally, although the cheaper and more familiar ammonia-based AVT became the virtual standard among nuclear utilities, Duquesne has hung on to morpholine throughout the operating history of Beaver Valley-1, an 810-MW nuclear power unit that started up in 1976.

Now, EPRI research at Beaver Valley has systematically analyzed the performance of morpholine-based AVT, including the nature and effects of its thermal breakdown products. And GPU Nuclear tests at Three Mile Island (TMI-1) have documented a 33% reduction in the iron oxide content of steam generator feedwater (a measure of corrosion) following a change from ammonia AVT to morpholine AVT. What's more, a gradual increase in pressure drop in the TMI-1 steam generator has been arrested, preventing progressive capacity loss during each operating cycle between refueling outages.



Deferring the need for cleaning the steam generator of corrosion by-products amounts to an estimated $1.1 million savings for GPU Nuclear, as well as enhancing TMI-1 availability. And preserving rated capacity represents potential generation worth some $13.2 million. In contrast, the morpholine AVT will cost only $41,000 (present value) more than ammonia over the next four years.

All this is particularly rewarding for EPRI project manager Tom Passell. He has specialized in water cycle chemistry for a dozen or more years, always on the watch for pH control agents with better distribution ratios. "That's the attraction of morpholine," he says. "It doesn't vaporize as readily as ammonia does. Only the liquid phase of the thermal fluid is corrosive, so that's where you want your anticorrosion additive to be—especially in wet steam piping beyond the high-pressure turbine."

Industry surveys and research under Passell's guidance have established ion chromatography for characterizing steam cycle impurities, built a credible database for morpholine AVT, explained its inconsistently reported breakdown products (organic acids that might offset its beneficial effect on pH), and also identified other amine candidates for AVT. "But morpholine stands alone for the moment," he says. "All seven once-through steam generators at U.S. nuclear plants are now using it. And so are 15 recirculating PWR units." About half of Canada's CANDU plants also use morpholine AVT, according to Passell, as do a gas-cooled Magnox station in England and 36 of the 49 units operated by EDF—Electricité de France. ■ *EPRI Contact: Tom Passell, (415) 855-2070*

New Guide Expedites Pumped-Hydro Evaluation

Pumped-hydro storage offers more than just some additional peaking capacity. It brings dynamic benefits to a utility system—capabilities for voltage, frequency, and power factor correction, and also the opportunity to minimize cycling of thermal plants.

But all this comes at costs that have been difficult to evaluate in a systematic way—either site versus site or against other storage alternatives. The problem is largely overcome by EPRI's new *Pumped Storage Planning and Evaluation Guide* (GS-6669), published in January of this year.

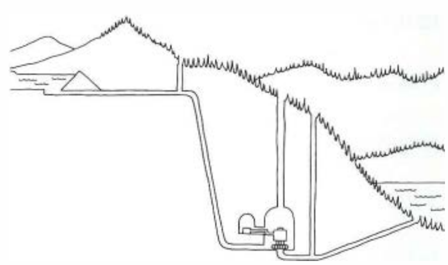
Brand-new technology is not the focus here. What's new is a comprehensive methodology for pumped-hydro screening and evaluation, grounded in extensive data from 35 facilities in 18 states (and one Canadian province), all but one of them put into service since 1954. The guide thus draws together a wealth of experience and consistently analyzes it in fully contemporary terms. Design criteria and concepts for various site-specific conditions are the result, including cost curves for major pumped-hydro project features.

Actually, two methodologies are presented. One is a coarse screening that can be done entirely with rough site parameters. The other is a fine evaluation for the few sites that look most attractive at the point of preliminary designs, specifications, and component cost estimates.

In addition to the costing methodologies, the guide includes PC-based software for assessing the dynamic benefits specifically related to pumped-hydro storage operation. These benefits are utility system specific, however, and calculating them requires user data.

"Any planner of energy facilities today can expect questions on his precision," says Chuck Sullivan, EPRI's program manager for hydroelectric generation and renewable fuels. "Utilities are justifiably sensitive about costs that may be disallowed in the regulatory process." EPRI's new methodologies for pumped-hydro evaluation therefore were independently reviewed for consistency with the real-world cost experience of 14 selected projects completed since 1963.

In terms of site costs, the predicted and actual data track well throughout the 27-year period—including a sharp transition in the early 1980s, when indirect costs rose disproportionately, probably because of more extensive administrative, regulatory, and quality control measures. The



EPRI methodologies tend to underestimate the indirect costs and overestimate the direct costs of recent years, but on balance, they accurately predict overall costs today. ■ *EPRI Contact: Chuck Sullivan, (415) 855-8948*

Market Assessment

Forecasting Market Adoption of New Technologies

by Thom Henneberger, Customer Systems Division

ABSTRACT *The decision to launch a new end-use technology or to market a new energy service often involves a careful evaluation of risks, costs, and benefits. Successfully performing such assessments depends on estimates of two market penetration factors: market size—how many customers will adopt a new end-use technology or participate in a new energy service offering—and market timing—when they will do so. EPRI-sponsored research is currently developing a market penetration analysis system to provide utility analysts with improved tools for forecasting both market size and market timing.*

New end-use technologies and energy services are having a profound effect on the electric utility market share. Some technologies, such as electric vehicles, represent major new markets for the efficient use of electricity. Others—such as advanced residential heat pumps, commercial thermal energy storage, and industrial adjustable-speed drives—may play a vital role in helping electric utilities meet their supply-side and demand-side objectives.

The demand for energy is driven largely by the number of energy-consuming products in the marketplace. New technologies or energy services can be a market opportunity for electric utilities or a competitive threat. The impact they will have on the way electric systems are planned and operated and on the way electric utilities serve their customers is a pressing issue. Forecasting market penetration—how many customers will adopt new technologies and services and when—is key to answering the challenge.

Market penetration analysis methods fall into two categories: judgment based and model based. Judgment-based methods are mental processes that people use to analyze data; inputs are translated into forecasts in the forecaster's head. These forecasts may be either simple or complex and can use either qualitative or quantitative data as input. Judgment-based methods rely implicitly on the experience and perceptions of the forecaster, which is both their strength and their weakness.

Model-based methods use well-specified algorithms to process and analyze data. The algorithms are repeatable by others and yield the same result if the same input data are used. Model-based methods also can use either qualitative or quantitative input data, but their crucial difference from judgment-based methods is that inputs are translated into forecasts in systematic, repeatable ways.

Both method types have strong proponents. Some argue for the exclusive use of one or the other approach. Proponents of model-based analysis may claim that judgment-based methods are unscientific. Proponents of judgment-based approaches may argue that model-based methods are black boxes or that modeling assumptions are unrealistic or overly simplified. Forecasting experts suggest, however, that using techniques that combine judgment and modeling can improve market penetration forecasts and offer significant savings in time and money. For example, one widely used technique employs model-based methods, but instead of calibrating the parameters econometrically, it establishes them by means of judgment.

Estimating market size

How big is the market for a new end-use technology or energy service? It has been said that estimating market size commands more attention, wastes more money, and frustrates more product managers than any other task. Nevertheless, it is a necessary first step for utilities in analyzing the market penetration of new technologies and services.

Market size is influenced mainly by market population and demographic trends; by market needs, as dictated by customer perceptions, attitudes, and beliefs; and by the functional characteristics of the product or service (e.g., its absolute market advantage).

Estimating market size is generally a two-step process. The first step is to develop an estimate of the maximum number of potential buyers in the market. Estimating this upper bound, called the market population, is both a counting and a screening exercise. It begins by counting the total population of decision makers in the market—which could be individuals, firms, or buying centers—and it ends by systematically excluding those for whom the decision to adopt is irrelevant. Screening rules must generally be developed and applied with judgment.

The second step is to estimate the fraction of the market population that will eventually adopt a new technology or service. Forecasters estimate this fraction by using a variety of judgment- and model-based methods. Sometimes experts familiar with the marketplace can accurately forecast either the market population or the market size directly. The strength of this expert-judgment approach depends on the insight and experience of the experts. The obvious difficulty is in identifying true experts.

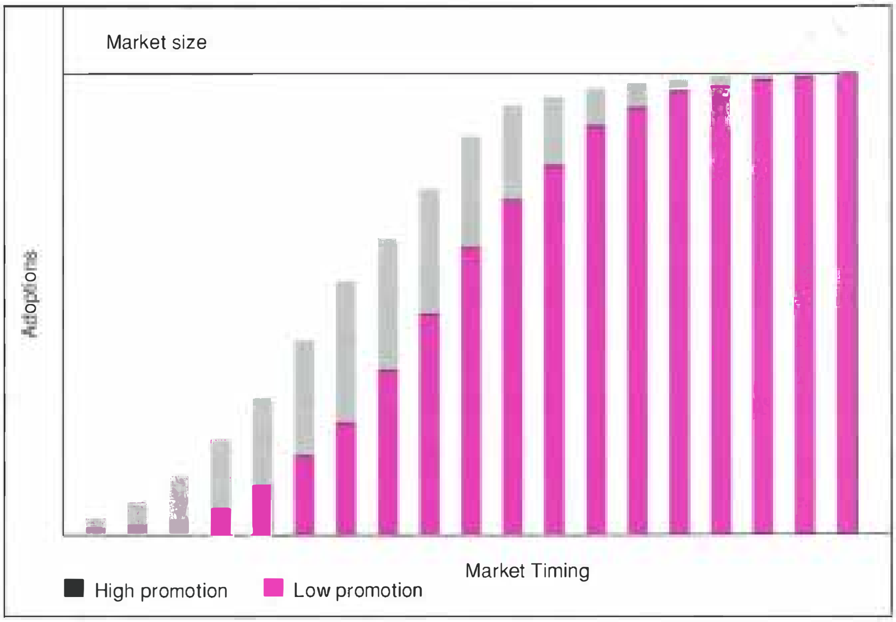
Another judgment-based method, the concept test, elicits the responses of a sample of potential adopters to concept statements about the technology or service being investigated. Concept statements describe the new technology or service in terms of factors that forecasters believe will affect customers' adoption choices. Faced with different concept statements, the potential adopters are asked to rank alternatives or to indicate which concepts they would adopt. Applying numerical analysis to concept-test results yields conditional estimates of the fraction of the market population that will adopt. The analysis can also produce information on customers' perceptions and attitudes about the new technology or service—information that can be useful in developing marketing strategies. In order to yield such richly detailed information about customers' perceptions, attitudes, and choices, most concept-test methods must of necessity be data intensive.

A simple model-based approach, the chain ratio method, estimates market size as a product of a series of ratios. To estimate market size for advanced commercial lighting systems, for example, forecasters might construct the ratio model

$$M = R_1 \times R_2 \times R_3 \times R_4$$

where M is market size, R_1 is the percentage of the market population that will find advanced commercial lighting economically attractive, R_2 is the percentage of commercial buildings that operate at least 12 hours a day, R_3 is the percentage of commercial buildings with floor space exceeding 10,000 square feet, and R_4 is the number of commercial buildings in the United States.

Figure 1 Forecasting the timing of customer adoptions of a new end-use technology or service is as important as forecasting the market size (i.e., the eventual number of adoptions). Increasing the level of the marketing effort can speed up adoptions.



The chain ratio approach is particularly useful if analysts can estimate ratios in the chain more easily than they can estimate the market population and the fraction of that population that will eventually adopt. The particular chain of ratios used depends on the specific product or service being offered, its relevant market or markets, the data available, and the judgment of the forecaster. Secondary data are often useful for estimating ratios.

Forecasting market timing

Knowing how large the market is for a new product or service is not enough; sometimes timing is everything. Experience shows that all innovations take time to diffuse (Figure 1). Market timing is affected by the level of marketing effort (pricing, positioning, and distribution); by the characteristics of potential buyers or participants (their decision-making style and degree of innovativeness); and by the characteristics of the market (its macroeconomic conditions, the degree of social interaction among potential adopters, and the strengths of competitive factors).

Forecasting the timing of market adoptions, like estimating market size, can be accomplished by means of either judgment- or model-based methods. An important judgment-based technique is historical analogy. With historical analogy, the forecaster assumes that the market timing of a new technology or service will mimic the adoption pathway followed by some analogous product that has already diffused into the marketplace. The key to a successful forecast is the choice of an appropriate analogy.

Model-based market penetration methods can be divided into two categories: adoption process models and diffusion process models. Adoption process models assume that potential customers pass through a sequence of stages that often begins with being unaware and ends with adoption or rejection. Different adoption process sequences may be appropriate, depending on the type of product or service being offered and its target market. One widely cited sequence for certain consumer products proceeds from awareness to interest, evaluation, trial, and eventually adoption or rejection.

To make adoption process models operational, the forecaster must estimate values for two sets of variables: the percentage of the market population initially occupying each stage of the adoption process, and the probability of making a transition from one stage to the next. Adoption process models may be structurally complex, may contain one or more feedback loops, and may be data intensive. Because they are often structurally robust, adoption process models can be extremely useful for explanation and sensitivity analysis.

Diffusion process models assume that market penetration of a new technology or service follows a characteristic time path. The underlying behavioral theory is that new technologies are first adopted by a few individuals, called innovators, who in turn influence others to adopt them. Diffusion process models are in general not structurally complex. Most are single-equation mathematical models that relate cumulative adoptions to time with one, two, or three parameters. Some diffusion process models include causal marketing-mix variables, and a few have more than two stages. Diffusion process models are most suitable for unconditional forecasting that makes use of early sales data or for judgment-based calibration. Because of their parsimonious nature, however, diffusion process models are not particularly useful for sensitivity analysis.

EPRI analysis tools

In 1988 EPRI surveyed 25 manufacturers of consumer durables and developers of industrial technologies and 42 electric utilities to determine the state of market penetration forecasting practice. The survey made the following important findings:

- U.S. industries, including electric utilities, are aware of many state-of-the-art methods, but the methods are not widely used.
- Inadequate data, the high cost of data collection, and the lack of a clear and systematic technical approach restrict the methods' use.
- Practitioners often find market penetration analysis methods difficult to communicate to decision makers, who may then fail to act on the analysis results.

EPRI's research into market penetration of new technologies and services is bringing together the best available analysis methods and assembling them into a system designed to meet the diverse needs of utility analysts. This system will provide demand-side program planners, marketing and customer service representatives, utility strategists, and demand forecasters with analytical power and problem-solving flexibility. It will help them to meet many of the challenges of successful market penetration analysis—specifically, to marshal limited resources, both in staffing and in funding; achieve quick turnaround; and perform sensitivity and risk analyses.

The keystone of EPRI's system will be its PC-based market penetration analysis software. Users will have access to state-of-the-art models for developing estimates of both market size and market timing. Tools will be provided for conducting sensitivity analysis, as well as for examining input data uncertainty. The market penetration analysis system will also include a library of market research survey questionnaires and interview guides. Utility analysts may use these instruments directly or customize them for special applications. An expert system will help users select the market penetration analysis methods most appropriate for the problem at hand.

Beginning this year, utility-hosted case studies will help EPRI researchers test and fine-tune the system. Lessons learned in the case studies and illustrative applications will be presented in an instructional guidebook. The research is scheduled for completion early in 1991. User support activities, including regional training workshops, a telephone help line, and a national users group, will be offered shortly thereafter.

Air Quality Control

Measurement of Nitrous Oxide Emissions

by Angelos Kokkinos, Generation and Storage Division

Much uncertainty remains, but many scientists believe that increasing atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several other gases may result in rising global temperatures. Although these gases allow solar energy to reach the earth, they trap surface heat (in the form of infrared radiation) that would otherwise radiate back into space. Hence they are called greenhouse gases. To date, most attention in this area has focused on the role of CO_2. But CH_4 and N_2O are also considered to be relatively strong absorbers of infrared radiation and thus potentially important contributors to the greenhouse effect. Both CO_2 and N_2O are produced during fossil fuel combustion.

N_2O is stable and long-lived. Therefore, in addition to acting as a relatively strong absorber of infrared in the troposphere, it eventually rises into the stratosphere, where it is the largest single source of nitric oxide (NO). Since NO is a major natural chemical sink influencing stratospheric ozone concentrations, increases in N_2O emissions could lead to ozone depletion at that level.

Combustion N_2O emissions

Fossil fuel combustion has not historically been viewed as a significant source of N_2O. Natural sources often cited are microbial nitrification, denitrification in soils and ocean surface water, lightning, and natural forest fires.

Other anthropogenic sources include fertilizer use and biomass burning. But recent measurements that show mean global N_2O concentrations to be increasing at a rate of 0.2–0.4% annually have led some investigators to suggest a link with fossil fuel combustion. These postulations are based on laboratory and field studies using grab-sampling techniques.

One of these studies has further postulated that N_2O emissions can be correlated with NO_x emissions—that is, with the combined emissions of NO and nitrogen dioxide (NO_2). Specifically, it postulates that combustion sources could be emitting N_2O at the rate of 25–35% of the measured NO_x. The study's data, shown in Figure 1, imply that a power plant emitting 1000 ppm of NO_x could be producing 250–350 ppm of N_2O. The data were subsequently used in concluding that fossil fuel combustion, principally oil and coal combustion by electric utilities, was the major anthropogenic source of N_2O.

However, recent results from EPRI-sponsored laboratory and field studies indicate that those measurements were wrong because of systematic errors in the measuring techniques employed, and that utility fossil fuel combustion is not a significant emitter of N_2O. Figure 1 also presents the EPRI results, which have been confirmed in independent testing by the Environmental Protection Agency.

The initial finding that the earlier studies were incorrect came as part of EPRI-sponsored investigations into simultaneous NO_x and sulfur dioxide (SO_2) control using a gas-fired combustion tunnel. In this research ammonia (NH_3) was doped into the fuel to increase NO_x levels, and SO_2 was doped into the combustion air to simulate coal combustion conditions.

Typical levels of N_2O associated with gas combustion are less than 10 ppm. Grab samples from this experiment, however, indicated concentrations of approximately 300 ppm. In order to confirm these results, samples were taken at a number of different stages of the combustion process, as well as at the furnace exit, and were analyzed. All N_2O concentrations were in the 300-ppm range.

ABSTRACT *EPRI-sponsored testing shows that because of systematic errors in the measuring technique used, previously reported high levels of N_2O emissions from fossil fuel combustion are incorrect. A new, on-line N_2O analyzer developed by EPRI helped confirm the discrepancy. Ongoing research is building a body of accurate N_2O emission measurements and investigating the formation of this gas, which is considered a significant contributor to the greenhouse effect and to ozone depletion in the upper atmosphere.*

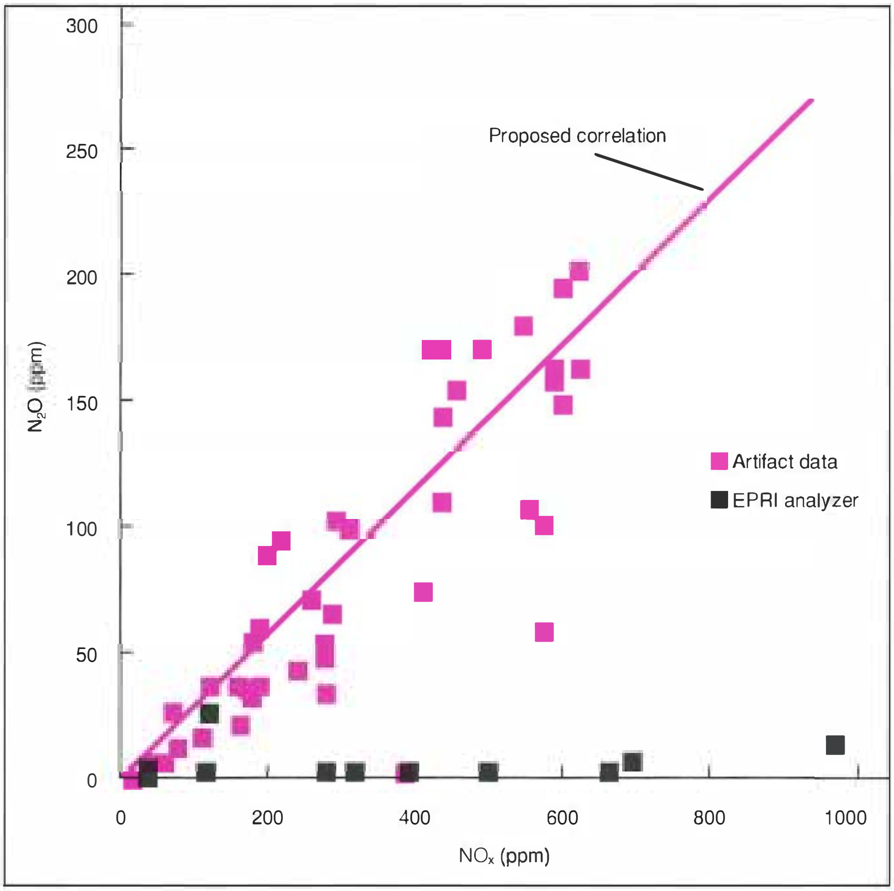
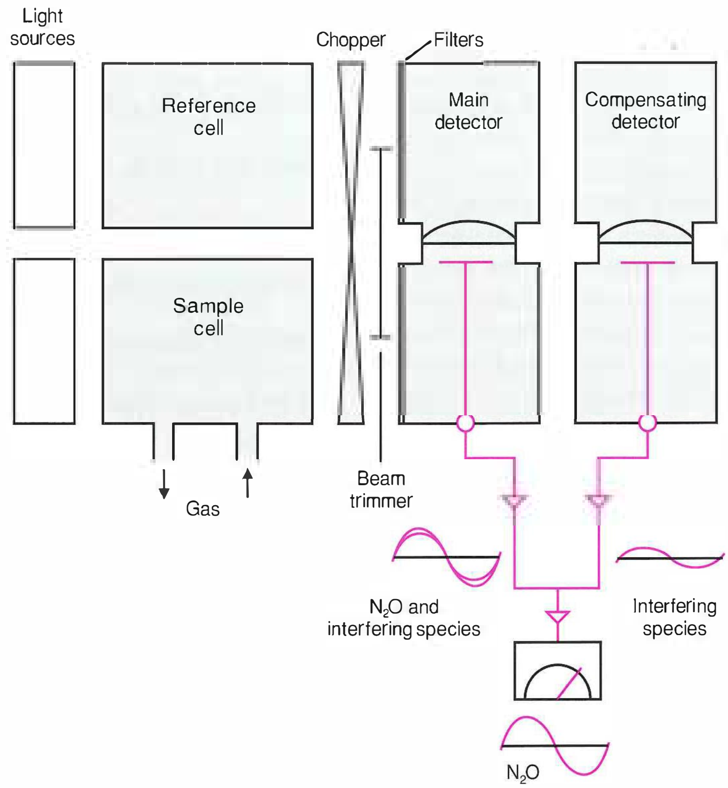


Figure 1 **N_2O emissions as a function of NO_x. The data gathered before the discovery of the sampling artifact are compared with data gathered by using the EPRI-developed analyzer. (Emissions have been corrected to 3% oxygen.) The analyzer data have confirmed that the earlier, high N_2O measurements (and the proposed correlation with NO_x emissions that was based on them) were erroneous.**

Additional tests were conducted to further explore these findings, and it was discovered that the N_2O readings fell back to less than 10 ppm when the SO_2 was removed. The researchers postulated that the SO_2 introduced into the combustion air was reacting in the sample flask with NO and water to create N_2O. They subsequently verified this reaction by using Pyrex containers filled with simulated flue gas mixtures. Only when SO_2 was added to the mixtures were significant N_2O concentrations measured.

The SO_2 concentration was found to be a significant factor in the reaction. Below SO_2 levels of 500–600 ppm, only a small amount of N_2O formed in the flask; at higher levels, N_2O formed rapidly. The time histories of SO_2, NO_x, and N_2O were also found to be significant (Figure 2). Most N_2O is formed within the first six hours. The relative speed of this reaction dictates that samples taken with gas chromatographs be analyzed immediately to avoid bias from the buildup of N_2O over time.

Figure 3 On-line N_2O analyzer, showing the infrared sources, the sample and reference cells, and the two detectors in series. The main detector senses N_2O plus interferences, while the compensating detector accounts for the interfering species.



On-line analyzer

Independently of these laboratory investigations, EPRI technical staff had expressed concern that combustion modifications being investigated for the reduction of NO_x emissions might increase N_2O emissions. They also questioned the earlier N_2O measurements, or at least the basis for the observed readings, because of their large scatter. In order to explore possible correlations between combustion conditions and N_2O, a research project was initiated (with funding from EPRI's Office of Exploratory Research) to develop an online analyzer capable of operating in the field and of providing consistent, instantaneous N_2O readings. Figure 3 is a schematic of the resulting nondispersive infrared analyzer.

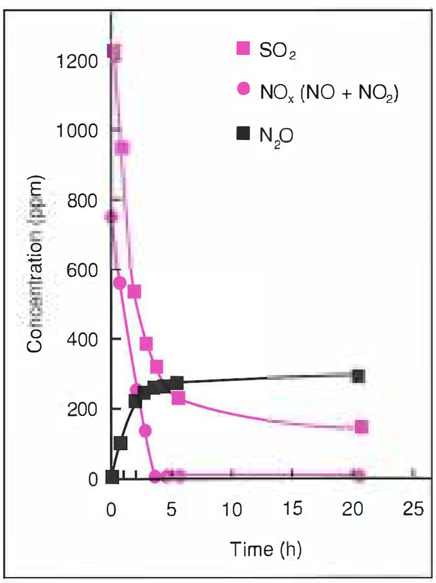


Figure 2 Time histories of N_2O, NO_x, and SO_2 during storage in sampling flasks. Results like these have demonstrated that over time, NO_x reacts with SO_2 in the presence of moisture to form N_2O in the flasks. (Emissions have been corrected to 3% oxygen.)

The analyzer is similar to systems used routinely to measure carbon monoxide (CO) and CO_2 emissions. It incorporates replaceable optical filters designed to detect N_2O in the infrared region of 7.8–8.5 micrometers. This region was selected to minimize the influence of interfering species. Both SO_2 and NO_2 appear in this region, however, and must be compensated for in order to measure N_2O precisely. To make these compensations, two Luft-type detectors are arranged in series within the analyzer. The two detectors are filled with N_2O under different partial pressures. The first, or primary, detector senses N_2O and any interfering gases that absorb in the 7.8- to 8.5-micrometer region. Since the first detector absorbs all the radiation from the N_2O bands but only a fraction of the other species, the second detector senses only the interfering species. It then electronically compensates for their effect.

Although the analyzer can compensate for interfering species, measurements are more accurate if the species are removed. The researchers removed NO_2 and SO_2 from a sample stream in the laboratory by using sodium carbonate and sodium sulfite. Subsequent testing confirmed that more-precise readings can be obtained in this way and that this type of scrubbing has no effect on N_2O levels.

Laboratory tests were also conducted to quantify the extent of potential interference from CO, CO_2, and NO and to verify the linearity of the analyzer. Results showed that in the range of 0–25 ppm of N_2O, the signal-to-noise ratio is large enough to detect a 0.5-ppm change in N_2O regardless of the concentrations of these other species. In addition, it was demonstrated that the analyzer does respond linearly to N_2O concentrations in both the 0- to 25-ppm range and the 0- to 250-ppm range.

After initial evaluation and validation in the laboratory, the analyzer was taken to 14 utility power plants to measure flue gas N_2O concentrations for a variety of combustion systems burning coal, oil, and gas (Table 1). The measured N_2O emissions from these sources were very low and were insubstantial in comparison with NO_x emissions. In all but three instances, N_2O emissions were below 5 ppm. The Environmental Protection Agency conducted simultaneous tests at six coal-fired sites with an on-line gas chromatograph and obtained similar, or even slightly lower, results.

It is likely that two of the high measurements in the EPRI tests—6 and 11 ppm—resulted from the generation of N_2O in the sampling line. This occurs when flue gas residues (condensed water, NO, and SO_2) are allowed to remain in the line between samplings. This problem can be avoided by flushing and heating the line before sampling is resumed.

The 23-ppm N_2O measurement shown for one of the oil-fired boilers in Table 1 is potentially attributable to the use of urea at that site. Investigations are being planned to assess the possibility that some portion of the NO_x that is reduced by urea may be converted to N_2O instead of to molecular nitrogen and water.

Table 1
N_2O EMISSION RESULTS FROM UTILITY TESTS

Type of Unit	NO_x (ppm)	N_2O (ppm)
Coal Fired		
Opposed-fired boiler	982	11
Opposed-fired boiler	692	6
Opposed-fired boiler	662	2
Tangentially fired boiler	498	1
Tangentially fired boiler	393	1
Tangentially fired boiler	390	1
Tangentially fired boiler	325	1
IGCC	19	1
Oil fired		
Front-fired boiler	268	1
Front-fired boiler	268	1
Front-fired boiler with urea injection	117	23
Gas fired		
Front-fired boiler	120	2
Opposed-fired boiler	NA	2
Combustion turbine	19	4

Note: Emissions have been corrected to 3% oxygen except for those from the combustion turbine, which have been corrected to 15% oxygen

Future directions

Taken together, these findings indicate that utility boilers are not significant emitters of N_2O. Nevertheless, further research is being planned. Apart from the urea investigations, this new work will focus on two areas.

In one effort, EPRI's Environment Division plans to investigate the possibility, considered unlikely, that some N_2O may be created by the reaction of NO_x and SO_2 in stack plumes. In the other effort, N_2O emissions from fluidized-bed combustors will be evaluated. Reports to date show that N_2O emissions from these units range from 30 to 200 ppm. EPRI's own preliminary data from the on-line analyzer indicate emissions in the range of 20–100 ppm. Research will attempt to define this range more precisely. Also, tests are planned to identify any operating conditions that would minimize N_2O emissions at fluidized-bed units.

Underground Transmission Cable

Monitoring Cable Systems

by Ralph Samm, Felipe Garcia, Tom Rodenbaugh, and John Shimshock, Electrical Systems Division

The existing underground transmission system in the United States is worth about $5 billion. To optimize the return on that investment and on further investment in the growing system, EPRI has sponsored research to develop periodic and continuous diagnostic procedures and methodologies for evaluating underground cables. By using monitoring results to support maintenance and cable management decisions, utilities will be able to improve maintenance planning, reduce unscheduled outages, increase system reliability, and extend cable life. At the same time, they will be able to operate systems more efficiently and closer to true ratings. The scope of EPRI's effort is seen in the following projects:

- Application of dissolved-gas analysis to the periodic monitoring of liquid-filled, paper-wrapped cables (RP7895-1) and also cables insulated with a laminate of cellulose paper, polypropylene film, and cellulose paper, or PPP-insulated cables (RP7910-1)
- Development of a transmission cable diagnostic system based on periodic power factor measurement (RP7910-5)
- Development of an integrated, multifaceted on-line diagnostic monitoring system known as the Dynamic Rating and Underground Monitoring System—DRUMS (RP7900)
- Development of a protocol for using perfluorocarbon tracers to locate leaks in high-pressure, liquid-filled cables (RP7905-1)
- A long-term cable life evaluation and management project, comprising 10 research areas (RP7914)

ABSTRACT *The early detection of problems in high-voltage, liquid-filled cables is critical to the management of most underground transmission systems. To make such detection possible—and thereby help utilities avoid forced outages, schedule corrective maintenance, and increase system reliability—EPRI is developing several techniques for periodic and continuous monitoring of cable systems. By using these techniques, utilities will also be able to operate cable systems more efficiently. In a related effort, tools are being developed for assessing the remaining life of in-service cable.*

Periodic monitoring

The technique of dissolved-gas analysis (DGA) involves determining the type, distribution, and concentration of gases extracted from dielectric-fluid samples that are taken periodically from equipment. Such gases are generated by the decomposition of insulation material and dielectric fluids under electrical and thermal stresses. The concentrations of various gases are often characteristic of specific types of degradation (e.g., degradation related to arcing or local overheating).

While the DGA technique has been applied successfully to oil-filled transformers, its use in cable systems has been comparatively limited, largely because of the lack of systematic data on the evolution, solubility rates, and diffusion rates of gases in high-pressure, liquid-filled (HPLF) cables. In work funded by EPRI with Detroit Edison's Warren Research Center, researchers developed a DGA-based method for determining the extent of deterioration in liquid-filled, paper-wrapped cables and for monitoring the condition of such cables.

To overcome the limitations of available sampling and analysis procedures, the Detroit Edison researchers developed an efficient, easily automated system that minimizes the transfer of fluids from container to container. With this system—called the EPRI Pressurized Oil Sampling System, or EPOSS—fluid can be directly drawn from installed cable, transported under pressure to a laboratory, and analyzed there by using gas chromatography.

Detroit Edison collected cable samples from in-service cable and then subjected them to thermal and electrical stress aging tests. Using a flow reactor and a gas chromatograph, the researchers monitored the evolution of gases during cable decomposition, developed needed background data on solubility and diffusion rates of pipe fluids, and built up historical profiles of standard aging on the basis of gas types and concentrations in several pipe-type cables. They also collected data on the gases that evolved during key types of failures in cable systems, and performed mechanical, electrical, and chemical analyses of paper to determine the loss of life associated with emergency temperature excursions.

Cable-aging profiles can prove valuable in analyses of utility cable. By comparing DGA results with the appropriate profiles, utilities can identify abnormal gas concentrations that may arise from internal thermal or electrical problems. In this way, DGA can be used as a principal tool for monitoring cable conditions and can warn of potential outages or maintenance problems.

To conduct this research, the Warren Center set up a well-equipped laboratory that is now available for use by utilities in developing gas histories for cables on their systems. The center offers an EPRI-licensed DGA service that can start with on-site extraction of samples, if desired. The licensed service team performs DGA, interprets the results, and determines how gas concentrations are related to operating conditions. If appropriate, a report on the findings is produced, including assessments of cable age and condition and recommendations on what corrective actions (e.g., fluid replacement, splice repair), if any, to take. By having analyses performed periodically, utilities can track cable conditions and note significant trends. Several utilities have used the service, and the center has incorporated the resulting data into a database being developed for use by the utility industry.

Detroit Edison is also performing DGA on PPP insulation and the associated impregnating and pipe dielectric fluids. (Impregnating fluid is the high-viscosity oil used to permeate the cellulose fibers of the paper tapes before they are pulled into pipes.) Utilities are likely to make extensive use of PPP-insulated cable in the future for two main reasons: its dielectric strength is 25–30% greater than that of paper-wrapped cable and its dielectric loss is less than one-third that of paper-wrapped cable. Detroit Edison has sampled and analyzed PPP-insulated cable just before installation in utility systems and has been accumulating records on the cable from the very first day of service. Those historical records can serve as reference points for the interpretation of DGA results obtained by utilities that later install PPP-insulated cable.

In another project, Power Technologies is pursuing a complementary technique for periodic cable monitoring. The goal is to develop a method and equipment for analyzing cable insulation in the field by measuring and regularly monitoring the insulation's power factor (tan delta). Researchers are also making a detailed technical analysis of insulation power factor and determining how changes in that factor are related to cable deterioration. EPRI is now field-validating a power factor monitoring and measurement system at its

Waltz Mill Cable Test Facility; it expects to have a portable measuring instrument available for field testing by the end of this year.

DRUMS

Over the years, utilities have come to better understand what properties and parameters should be monitored in order to recognize potential problems before they can impair cable reliability. Under EPRI contract, Underground Systems is developing the Dynamic Rating and Underground Monitoring System, an integrated system consisting of (1) sensors located at distinct points in a cable system, (2) communication techniques that provide for data transmission from the sensors to terminal points, and (3) computer-based methods of analyzing data to obtain information on the operational state of the cable system. To minimize the amount of hardware to be installed on new systems or retrofitted on existing systems, data transmission through the pipe itself is under investigation.

DRUMS features a dynamic rating component that will enable utilities to optimize operation of force-cooled cable systems by predicting available loading levels under a variety of conditions. This component will perform real-time monitoring of loading, soil and pipe temperatures, and fluid flow parameters. The monitoring results will then be used as input to computer models of system thermal and hydraulic performance. This component is under test on a feeder cable belonging to Consolidated Edison Co. of New York, the nation's leading user of underground transmission.

Another principal element of DRUMS—a fluid-leak-detection component—will use the results of real-time monitoring to model the hydraulic state of the cable system. That model can then be used to dynamically model the flow of fluid into and out of system reservoirs. The difference between computed and actually measured fluid flow rates will indicate the presence of a leak. This component has been successfully demonstrated on a Con Edison–Long Island Lighting tie, where a simulated leak of just 1.25 gallons an hour was detected.

The rapid location of faults in underground transmission systems is of critical importance to utilities in minimizing costs and maintaining system reliability. Available fault-locating techniques are frequently time-consuming. In the event of an electrical fault in a cable system monitored by DRUMS, the resulting pressure pulse generated in the pipe-filling liquid would be detected by sensors at adjacent manholes or at both ends of the system. Using the relative time of arrival of the pulse at two or more sensors, DRUMS would then perform calculations to determine the fault location.

DRUMS will also include components that will monitor cable terminals, pipe coating, and cable joints and thereby help utilities avoid unsafe operation. Eventually, EPRI may attempt to enhance DRUMS by incorporating computer-based expert systems that can draw on DGA results and power factor measurements, as well as DRUMS databases, to automate diagnosis and help users interpret data streams.

Locating fluid leaks

Leaks of fluid from HPLF pipe-type cable that are caused by defects or corrosion can result in forced outages. Although DRUMS should make it easier to detect leaks, locating them is another, often very difficult task. Of the commercially available leak-locating techniques, EPRI has found that tagging the pipe-filling liquid with a tracer gas or vaporizable fluid is the most promising. Of the various candidate materials, perfluorocarbon tracers (PFTs) appear to be best. In addition to being nontoxic and compatible with HPLF cable materials, PFTs exhibit good dielectric properties and are suitably soluble in the most commonly used pipe-filling fluids under the normal range of operating conditions. Moreover, PFTs are detectable at extremely small concentrations, and background levels of PFTs in the atmosphere are so low as to make contamination unlikely.

Brookhaven National Laboratory—under the joint sponsorship of Empire State Electric Energy Research Corp., Con Edison, and EPRI and with support from Cablec Corp.—is developing a detailed, readily applicable protocol for using PFTs in locating HPLF cable leaks. If the effort is successful, the protocol should be available by late 1992.

Cable life evaluation and management

HPLF cable was introduced in the United States during the 1930s. Utilities made major application of this cable technology at 230- and 345-kV levels in the mid-1950s and the mid-1960s, respectively. Many systems are nearing 40 years of age—an age generally agreed to constitute an acceptable lifetime for a transmission cable system. Many cable engineers, however, believe that pipe-type cable systems age little when operated under typically conservative utility conditions and that cable life may exceed 80 years.

Utilities need to know if existing systems will be ready for retirement at 40 years. The prevailing maintenance philosophy is reactive: cable is retired when the failure rate becomes unacceptable, that is, when maintenance costs and outages become burdensome. Given the increasing importance of transmission system reliability, predictive maintenance and planned replacement based on an intelligent diagnosis of cable system conditions represent a far preferable approach. Therefore, EPRI has mounted a comprehensive research project aimed at enabling utilities to determine the life expectancy of in-service cable. The project will explore 10 interrelated research areas to meet the following objectives (in order of technical priority):

- Determine end-of-life criteria
- Develop a diagnostic tool that uses fluid sampling to evaluate aging
- Determine the rate of deterioration of insulating paper
- Perform qualification testing of thermomechanical bending–conditioned cable
- Develop improved monitoring techniques
- Document field handling and laboratory measurement techniques
- Test oldest 138- and 345-kV cables
- Assess the effects of corrosion
- Determine the effect of intense fluid pumping on force-cooled cables
- Develop techniques for evaluating the deterioration of lead and lead alloys

If successful, this project—which will draw on and support EPRI cable-monitoring efforts—will supply a rational basis for decisions on cable replacement and management.

BWR Water Chemistry

by Daniel Cubicciotti and Robin Jones, Nuclear Power Division

The high-purity water used in boiling water reactors (BWRs) as the neutron moderator and primary coolant contains very small concentrations of ionic impurities. During power operation the coolant also contains small amounts of dissolved hydrogen, oxygen, hydrogen peroxide, and other oxidizing species as a result of radiolysis, recombination, and liquid-vapor phase partitioning processes occurring in and near the core. Even at the lowest achievable ionic impurity concentrations, the presence of oxidizing radiolysis products makes the BWR coolant aggressive enough toward Type 304 and Type 316 stainless steels to promote intergranular stress corrosion cracking (IGSCC) in weld-heat-affected zones, where the high tensile stresses and sensitized microstructure also necessary for IGSCC often can coexist.

The addition of hydrogen to feedwater was identified in the first phase of the BWR Owners Group (BWROG) IGSCC research program as a possible method for reducing the concentration of oxidizing radiolysis products in the coolant and thereby decreasing the likelihood of pipe cracking. One major task of the program's second phase was to develop, field-test, and evaluate the effectiveness of this IGSCC remedy concept, which is known as hydrogen water chemistry (HWC). The work undertaken included laboratory and in-plant tests to quantitatively establish the effects of BWR water chemistry variables on IGSCC (and thereby define the HWC conditions that would have to be achieved to mitigate cracking), together with longer-term field trials to verify the benefits of HWC and investigate potential adverse consequences of its use.

ABSTRACT *Cracking in the recirculation system piping of BWRs has been a costly problem in terms of lost availability. EPRI research has shown that changes in water chemistry can mitigate this problem. In particular, adding hydrogen to plant feedwater has proved to be effective in reducing the oxidizing radiolysis products that promote stress corrosion cracking. Working with the BWR Owners Group and other industry representatives, EPRI has published guidelines for the implementation and use of this remedy, known as hydrogen water chemistry. Ongoing work is aimed at adapting HWC to protect BWR reactor vessels and internals.*

Defining HWC requirements

An extensive laboratory test program was begun in 1980 to document the effects of BWR water chemistry variables on the corrosion and corrosion cracking of structural materials. The materials studied included stainless steels, Inconels, carbon steels, and low-alloy steels, and the water chemistry variables were ionic impurity concentration, dissolved-oxygen concentration, and temperature. Corrosion phenomena investigated were general corrosion, crevice corrosion, corrosion fatigue, hydrogen embrittlement, and stress corrosion cracking.

Test results indicated that IGSCC damage to BWR recirculation system piping most likely occurs mainly during power operation. The recirculating coolant is at a temperature of about 288°C during power operation and typically contains about 200 ppb of dissolved oxygen and smaller quantities of other oxidizing radiolysis products, resulting in a stainless steel electrochemical corrosion potential (ECP) of about 0.05 V on the standard hydrogen electrode (SHE) scale. Laboratory tests showed that ionic impurities and dissolved oxygen independently influence the IGSCC behavior of sensitized austenitic stainless steels at 288°C. At ionic impurity levels typical of those in reactor water during power operation (i.e., conductivity below 0.3 μS/cm), IGSCC was found to be effectively suppressed at dissolved-oxygen concentrations below about 20 ppb, which resulted in stainless steel ECPs below about −0.23 V (SHE).

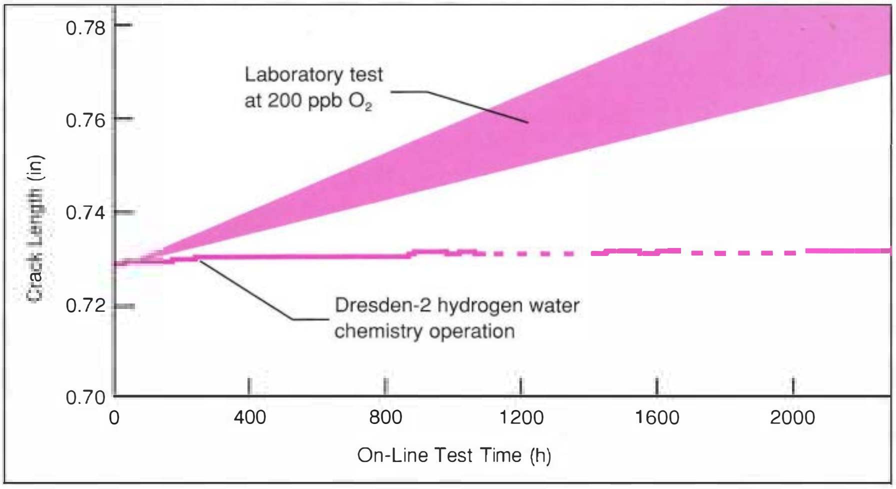
By 1982 the laboratory test data clearly indicated that reducing the content of oxygen and other oxidizing radiolysis products in BWR coolant during power operation should result in a more benign service environment for structural materials. An earlier study cosponsored by General Electric, Commonwealth

Edison, and the Department of Energy had suggested that the addition of hydrogen to feedwater was a promising approach to reducing the oxygen content of recirculating coolant, and a short-term Swedish in-plant test had demonstrated the feasibility of this approach. Accordingly, in 1982 DOE, GE, EPRI, and Commonwealth Edison sponsored a one-month test at the utility's Dresden-2 plant to assess the feasibility of implementing HWC as a long-term pipe-cracking remedy. The test found that:

- The oxygen concentration in the recirculation system could be reduced to low levels by hydrogen injection.
- The in-reactor IGSCC behavior of sensitized Type 304 stainless steel was similar to the in-laboratory behavior, and IGSCC could be suppressed at practical hydrogen injection rates.
- Hydrogen injection increased the steam line radiation fields and the environs dose rates during power operation because nitrogen 16 (always formed in the core) partitioned into the steam under the more reducing conditions created by hydrogen injection instead of staying in the recirculating water.

After the one-month test, EPRI, Commonwealth Edison, and GE cosponsored a long-term project at Dresden-2 to confirm the feasibility of full-time HWC operation. This project has completed three 18-month operating cycles and has verified that plant operation in the IGSCC-suppression regime is possible for more than 90% of the time at power, and that the rate of IGSCC in sensitized stainless steel specimens exposed to water taken from the recirculation system is reduced to low levels (Figure 1). Moreover, the steam line radiation field increase at Dresden-2 has proved to be manageable and to have a negligible impact on personnel radiation exposures. Other adverse-effects studies have revealed no major negative impacts of hydrogen injection on plant operations, fuel performance, or shutdown radiation fields.

Figure 1 Crack length versus time for sensitized Type 304 specimens tested at Dresden-2 and in the laboratory. The addition of hydrogen to the feedwater at the Dresden-2 BWR minimized the rate of IGSCC by reducing the water's oxygen concentration.



By 1986 short-term tests of hydrogen injection had been conducted at six GE-type BWRs. The results showed the response to hydrogen injection to be plant-specific. For example, different relationships were observed in different plants between the feedwater hydrogen concentration and the ECP of stainless steel in recirculation system water. However, stainless steel ECPs below −0.23 V (SHE) were attained in all the plants. And as the data in Figure 2 indicate, when this ECP is established in conjunction with a low ionic impurity concentration, IGSCC is suppressed. (Only recently has it been possible to explain the plant-to-plant variation in the feedwater hydrogen concentration required to achieve a particular oxygen concentration in the recirculation system. Modeling studies have revealed that the hydrogen concentration requirement can be correlated with plant-specific variations in the radiation dose rate in the downcomer region.)

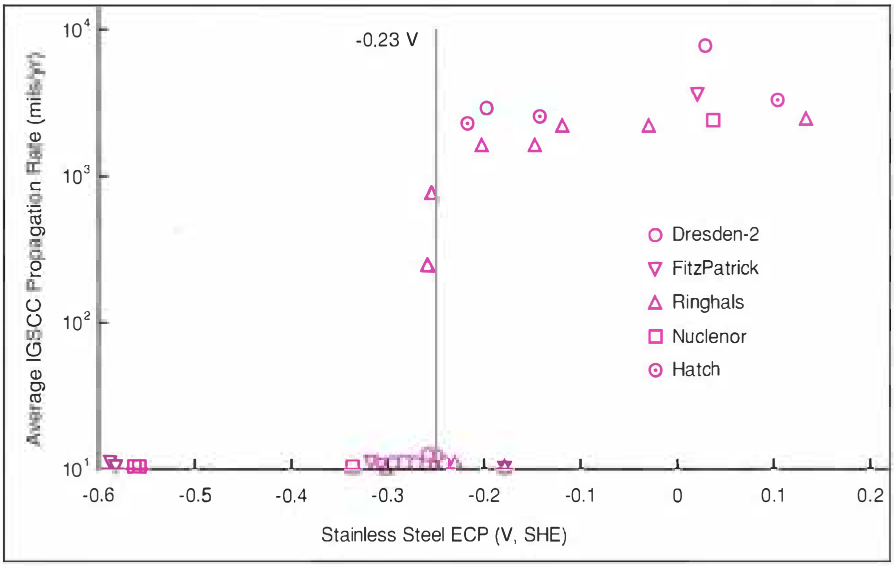
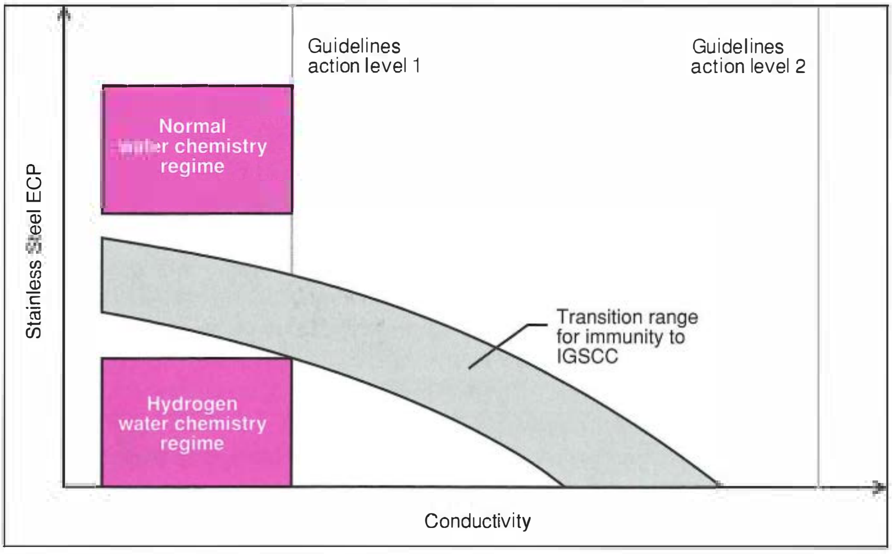


Figure 2 Results of in-plant tests at several BWRs showing the relationship between the rate of IGSCC for sensitized Type 304 stainless steel and the stainless steel's electrochemical corrosion potential. Operation in the hydrogen water chemistry regime (with an ECP below −0.23 V) resulted in very low crack propagation rates.

Developing guidelines

The development of water chemistry guidelines was the method chosen for transferring

Figure 3 The rate of IGSCC in BWR stainless steel piping increases as reactor water conductivity (related to ionic impurity levels) and the steel's electrochemical corrosion potential (related to dissolved-oxygen content) increase. In tests of sensitized steels, IGSCC was not detected below the transition range shown here. To help plants operate below that range, the hydrogen water chemistry guidelines add recommendations on ECP level to the conductivity and other control parameters specified in the normal water chemistry guidelines.



the findings of the BWROG–EPRI program to the BWR utilities. These guidelines are industry consensus documents prepared by committees that include representatives of utilities, nuclear steam supply system vendors, and consulting firms. EPRI's role is to facilitate the committees' work and to publish the resulting documents.

The first guideline document, published in 1985, identified the chemistry parameters that should be controlled during plant operation to minimize IGSCC in stainless steel piping while maintaining satisfactory fuel performance and radiation field buildup. Recommended levels were provided for each of these control parameters, together with suggested actions to be taken if the recommended levels were exceeded. The document focused on chemistry controls for normal water chemistry (NWC) operation and provided preliminary information on HWC operation.

By 1987 enough new information had been gathered to warrant a revision of the guidelines. It was decided that the available data were sufficient to allow the preparation of separate documents for NWC and HWC operation. The resulting NWC document (NP-4946-SR) had one major change from the 1985 guidelines—the addition of reactor water sulfate concentration as a control parameter during power operation. This change was made on the basis of laboratory and in-plant tests that showed sulfate to be a very aggressive impurity with respect to IGSCC of sensitized stainless steels.

The goal of the HWC guidelines committee was to define a practical BWR water chemistry specification that would minimize IGSCC in Type 304 stainless steel recirculation system piping while maintaining acceptable fuel performance and field buildup; protection of reactor internals was not considered. The committee wanted to make the HWC guidelines consistent with the NWC guidelines in as many respects as possible, so that no major perturbations in plant chemistry control programs would be required if hydrogen injection was interrupted.

After an extensive review of laboratory and in-plant test results, the committee found it necessary only to add stainless steel ECP (measured in an autoclave connected to the recirculation system) to the control parameters specified for power operation; all other control parameters and values remained the same as in the NWC guidelines. Figure 3 illustrates the relationship between the two chemistry specifications. (The oxygen content of the recirculating coolant was considered as an alternative to ECP as the key HWC control parameter, but it proved impossible to specify a single oxygen concentration that would provide IGSCC protection on a generic basis.) The final version of the HWC operating guidelines document (NP-4947-SR) was published by EPRI in December 1988. Also developed was a companion document (NP-5283-SR-A) that presents generic, NRC-accepted guidelines for the design, construction, and operation of HWC installations at BWR plant sites.

Together, the HWC operating and implementation guidelines provide U.S. utilities with a recommended chemistry specification and an NRC-approved approach for implementing HWC in their plants. Seven U.S. BWR plants and five foreign plants were using HWC as of last summer, and near-term adoption is planned at many other plants. Although no plant has yet used HWC as the basis for a request to the NRC to grant relief from augmented piping inspection requirements, several plants plan to make such requests in the near future, and BWROG is considering making a generic submittal. NRC approval would signify its endorsement of HWC as an effective remedy for BWR pipe cracking.

Ongoing efforts

In the course of its work, the HWC guidelines committee identified several areas of uncertainty regarding HWC operation, including:

- The degree of SCC protection achieved elsewhere in the coolant circuit during HWC operation under the current, recirculation-piping-oriented guidelines
- The relationship of measurements made in autoclaves to the conditions actually experienced by recirculation system piping
- The rate of SCC damage accumulation during periods when the ECP or ionic impurity concentrations exceed the guideline values
- The effects of HWC on fuel performance beyond three cycles
- The effects of dissolved copper and zinc on ECP, crack growth, and fuel performance

EPRI research is addressing these uncertainties, with particular emphasis on adapting

HWC to protect BWR reactor internals against cracking. Many internal components use the same materials as BWR piping and are fabricated by means of similar methods; hence they are potentially susceptible to SCC. Access limitations make inspection of many of these components difficult, and regulatory concern over potential safety implications is increasing. This concern is supported by field experience as well as current data and models. Numerous components have already cracked. For components that are fairly easy to replace, cracking is chiefly a reliability issue. Safety concerns are mainly confined to major core support structures (e.g., core support plate, core shroud, and top guide) and to attachment welds. Current information suggests that these components may be SCC-susceptible.

Although mandatory inspections are unlikely in the short term, it is probable that the inspection of major internals and attachments will be required in the longer term. The potential cost impact on utilities is expected to be large, since it is likely that detailed inspections will reveal damage to some internals at some plants. Because access restrictions will make the repair of many internals and attachments very difficult, HWC operation is an attractive remedy option—particularly if HWC can be adapted to protect the least-accessible components, such as those below the core.

The goal of future EPRI HWC development work is to provide, by 1993, a technical basis for revised BWR water chemistry guidelines that will prevent, or substantially mitigate, SCC problems in BWR pressure boundary components and reactor internals while maintaining satisfactory fuel performance and minimizing radiation field buildup. In addition, the work will resolve the other issues identified by the HWC guidelines committee. Planned R&D activities for achieving these objectives include the development of improved, plant-specific BWR chemistry models and the generation of an extensive body of benchmarking data via systematic laboratory tests, test reactor studies, and in-plant measurement programs at selected BWRs. Work in these areas began in early 1989 and is expected to continue for several years.

Control and Information Systems

Knowledge Based Technology Applications Center

by Bill Sun, Nuclear Power Division

ABSTRACT *In order to assist member utilities with expert systems technology and applications, EPRI established the Knowledge Based Technology Applications Center in late 1989. The center, located at Syracuse University and operated jointly with Kaman Sciences, is geared toward informing utilities about expert systems and providing them with support in key areas: project scoping, prototype development, and the integration of expert systems into operations, maintenance, engineering, and administration.*

The Knowledge Based Technology Applications Center (KBTAC) provides several kinds of technical support to utilities, enabling them to develop expert systems that address important problems in power plant operations, maintenance, engineering, and administration. The initial focus of the center has been on applications for nuclear power plants.

As a central clearinghouse for information, KBTAC helps utilities select expert systems applications consistent with their internal resources. Utilities can experiment with and evaluate problem-solving alternatives before making an internal or commercial commitment. The center not only provides technical support with specific applications problems—with an emphasis on project scoping and the design of prototype expert systems—but also provides technology transfer programs to help utility engineers stay abreast of evolutionary changes in expert systems technology.

Information clearinghouse

Member utilities have electronic access to the various KBTAC databases. The expert systems tool database provides information on commercially available tools and shells, and the prototype database offers information on EPRI-developed tools and expert systems. The life-cycle and project database contains information on utility expert systems development; the intent is to provide a vehicle for EPRI member utilities to share information on their expert systems applications.

An electronic bulletin board provides users with clearinghouse database information, news bulletins, schedules of planned events, information on topics of special interest, data on various support groups, message-passing capabilities, and utility points of contact. The KBTAC staff expertise database provides infor mation on the expert systems support available from the staff at the center. All the databases are supplemented by a program of quarterly newsletters and periodic bulletins.

Technology transfer

The technology transfer program is a series of seminars, training courses, and workshops. KBTAC's first offering, called Seminar on a Disk, was released in January 1990. Supplemented with an overview of KBTAC, it introduces expert systems applications for utilities and requests responses to two brief questionnaires designed to help the center further develop the program to make it fully responsive to the needs of member utilities.

Another offering, the Management Seminar, is designed to introduce utility managers to KBTAC and to establish a dialogue on how expert systems can improve productivity in their respective utilities.

The Introductory Expert Systems Development Seminar is a four-day course that provides a broad overview of expert systems, discusses the types of problems appropriate for solution by expert systems, reviews the integration of expert systems technology with conventional applications, and familiarizes participants with the issues surrounding the implementation of expert systems. Each participant will become familiar with one expert system shell and gain enough knowledge to build a small to intermediate application.

The Prototype Development Workshop is intended to facilitate a collective approach among a group of utilities in order to develop a prototype expert system that addresses their common problems. Technical support will be available to the group to refine and further develop this application and implement it into utility operations.

Technical support

The technical support program helps member utilities develop working expert systems and integrate them into their operations. KBTAC provides individual utility support, offers both commercial tools and prototype expert systems developed by EPRI and EPRI member utilities, fosters and coordinates users groups, and conducts an annual program development workshop.

Individual utility support varies from telephone consultation to the opportunity for a utility engineer to spend a few weeks at KBTAC working with a staff member. Initial support consultations concentrate on project definition and scoping and on problem conceptualization and formulation. Equally important, however, is continuing support, which is available throughout the project life cycle.

In offering expert systems tools and providing education in their use, KBTAC makes it possible for utility engineers to explore the various offerings and conduct preliminary prototyping. Their findings then contribute to the tool database and support technology transfer.

The objective of the users groups is to form a bridge between KBTAC and those who use its services. The proposed functions of these groups are to identify common problems to be solved in the prototype development workshops, to critique KBTAC programs to ensure responsiveness to utility needs, and to create a liaison between the center and the utilities.

Facilities

Located at Syracuse University, KBTAC has a wide variety of computer clusters that can be used for instruction, training, and technical support. These include a terminal cluster connected to the university mainframe, an IBM PC cluster, an IBM PS/2 cluster, an Apple Macintosh cluster, a SUN Workstation cluster, and LISP and AI workstations.

KBTAC houses a range of expert systems software, from programming languages to shells, on microcomputer and mainframe environments. The center's software capabilities are continually being expanded to meet the needs of participating utilities.

Environmental and Health Assessment

Mercury in the Environment

by Donald Porcella, Environment Division

Two decades ago, mercury (Hg) was considered a problem only for industries that discharged liquid wastes containing Hg directly into water bodies. The recent discovery of elevated Hg concentrations in fish from lakes remote from anthropogenic sources has raised new concerns among health authorities. Many of these lakes contain fish whose flesh exceeds state health advisory concentrations for Hg (0.5 ppm). The Hg in fish flesh is almost entirely present as methyl-Hg, the form of Hg most toxic to humans. The fish do not appear to be affected by the Hg, however; thus it is not an ecological but a public health concern. To address this concern, the sources and processes that control Hg cycling in aquatic ecosystems are being measured so that Hg accumulation by fish can be reduced.

Two linked hypotheses have been suggested to explain elevated Hg in fish: that Hg deposition from the atmosphere is the major source of Hg for fish in these remote lakes, and that acidic deposition can increase Hg

ABSTRACT *EPRI researchers are testing two major hypotheses about health risks associated with mercury cycling: that atmospheric deposition accounts for most mercury accumulated in fish, and that acidity enhances mercury accumulation by fish. Results suggest that the hypotheses are true, but the underlying mechanisms need elucidation. Research indicates that in situ bioremediation may be an effective mitigation option.*

accumulation by fish. These hypotheses are being tested in ongoing EPRI research.

Research activities

In the early 1980s, EPRI funded the development of analytical methods for measuring Hg in the environment because existing methods were too insensitive for air and water samples. In addition, samples and apparatus were contaminated by Hg from ambient air and water. Contamination will occur without very careful, clean sampling and ultraclean laboratories. At that time, attempts to assess the processes governing Hg accumulation by fish failed to account for the apparent Hg pools in the water and food chain, because transfer rates would have had to exceed reasonable bounds. The problem was that most of the reported measurements of Hg in water were incorrect. Since more-sensitive techniques have been developed, researchers know that reported Hg concentrations in freshwater lakes are almost all too high, sometimes by as much as a factor of 10,000. At a symposium on trace metals in lakes held in Toronto in August 1988, it was concluded that almost all trace metal concentrations reported for the Great Lakes were at least a factor of 10 too high.

Recent improvements in sampling and analytical techniques by EPRI's contractors permit measurements of the different forms of Hg at concentrations of less than a nanogram per liter. For example, the data in Figure 1 show analyses improving in accuracy by a factor of 500 over a four-year period as a result of clean laboratory and field techniques. Field standards and blanks confirmed the improvement in accuracy, and the results allowed the initiation of field studies to evaluate Hg biogeochemical cycling into fish.

Before beginning the field research, task force advisers requested that the relationship between Hg in fish and pH be demonstrated with EPRI-sponsored research. A cooperative study with the EPA National Surface Water Survey, performed as part of the National Acid Precipitation Assessment Program, resulted in the efficient use of EPRI research funds. Sampling of fish from lakes in the upper peninsula of Michigan, an area remote from known anthropogenic Hg sources, indicated that 15% of the fish exceeded the Hg health advisory level for the state of Michigan (0.5 ppm), while 60% of the lakes contained at least one fish that exceeded this level.

The Hg-pH relationship from that study (Figure 2) is weak but is sufficient to show that there is an association. The figure shows two other factors that appear to influence the amount of Hg accumulated by fish. First, if the lake is a drainage lake (observed inflow and outflow), watershed inputs from weathering could be a dominant source of Hg; a seepage lake will be dominated by atmospheric deposition of Hg. Second, the amount of dissolved organic matter is thought to affect Hg availability for accumulation by fish.

Using these results and the sampling and analytical improvements from the earlier research, EPRI initiated biogeochemical studies in the summer of 1988 with the Mercury in Temperate Lakes (MTL) Project (RP2020-10). MTL researchers are comparing geologic and atmospheric sources of Hg and measuring by

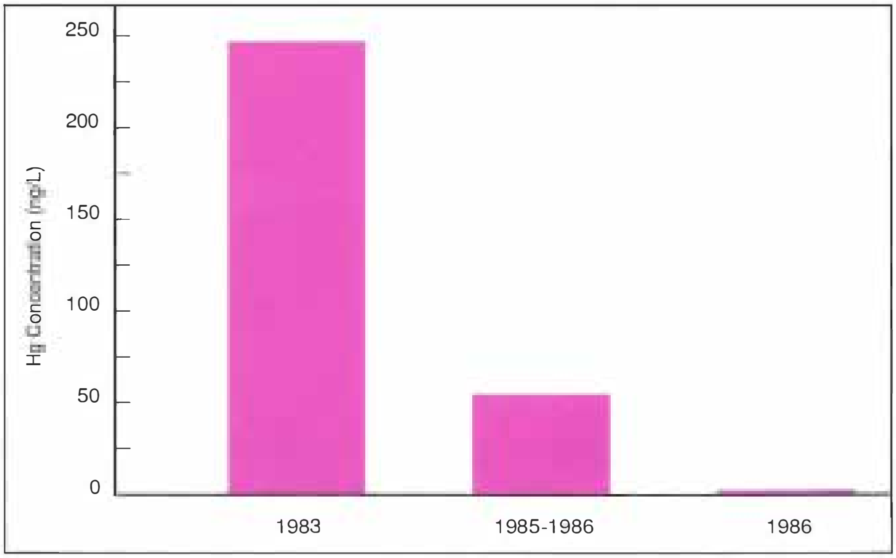
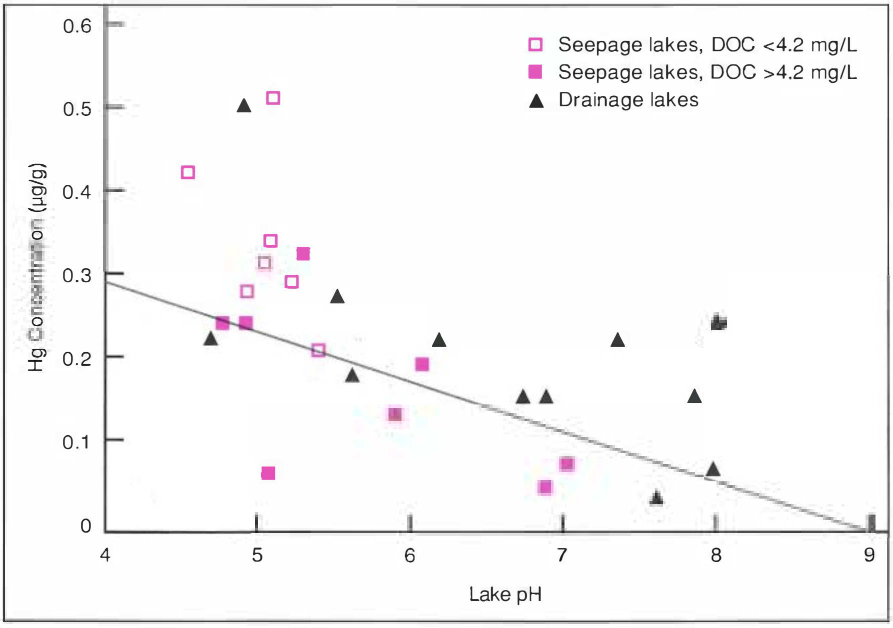


Figure 1 Reported Hg concentrations in a Wisconsin seepage lake. Greater accuracy is obtained as better sampling and laboratory techniques are implemented: the 1986 value of 0.25 ng/L is consistent with deposition measurements.

Figure 2 The association between lake pH and the concentration of Hg in the muscle tissue of three-year-old yellow perch suggests cause and effect; however, other factors, such as lake type and the amount of dissolved organic carbon (DOC) in a lake, have significant influence on the association.



field experiment, in a set of five seepage lakes in northern Wisconsin, how environmental factors affect fish Hg concentrations. The Wisconsin Department of Natural Resources, along with five universities and two consulting firms, has focused on Hg deposition and cycling in seepage lakes. To provide important comparison data, EPRI is funding an exchange of information and analytical and sampling protocols with an Ontario Ministry of the Environment study of Hg in drainage lakes. Similar sampling and analysis occur in both projects, and some of the process studies have common investigators.

Some initial estimates of Hg balances in the seepage lakes in Wisconsin indicate that atmospheric deposition can account for all of the Hg in the fish community (Figure 3). Total measured Hg concentrations in precipitation are 3–30 times higher than concentrations in surface waters. Although the atmospheric deposition hypothesis requires additional testing, the researchers have confirmed its dominance in seepage lakes.

The role of environmental factors will be explored by evaluating results from two years of field data collection (to be completed in 1991). For example, as noted above, initial measurements indicate that fish collected from lakes at low pH have higher Hg than fish from lakes at higher pH, but that other environmental factors are involved. These factors include organic carbon, which may bind Hg and affect its availability to organisms, and redox conditions, which may affect the rate of methylation of inorganic Hg.

EPRI is also sponsoring a related project on Hg biogeochemistry at a California reservoir contaminated with Hg mine wastes that enter through surface water. First-year results from this study indicate that the estimated loss of elemental Hg is an important fraction of the tributary inflow of Hg, and they suggest in situ bioremediation as a potential mitigation strategy for the lake. The California results are also providing information on a drainage lake that can be compared with results from the Wisconsin study.

Known mitigation opportunities are limited, but new EPRI research on biochemical processes shows promise. The MTL effort is closely coordinated with exploratory research on genetic ecology (ER8000-25; *EPRI Journal*, January/February 1990, p. 38). This research has developed in situ bioremediation as a potential mitigation tool for managing environmental Hg. The bioremediation research depends on identifying the environmental factors that control production of the different forms of Hg. Increasing the production of elemental Hg by microbially induced reduction of the mercuric ion [Hg(II)] and demethylation of methyl-Hg will enhance the loss of lake Hg to

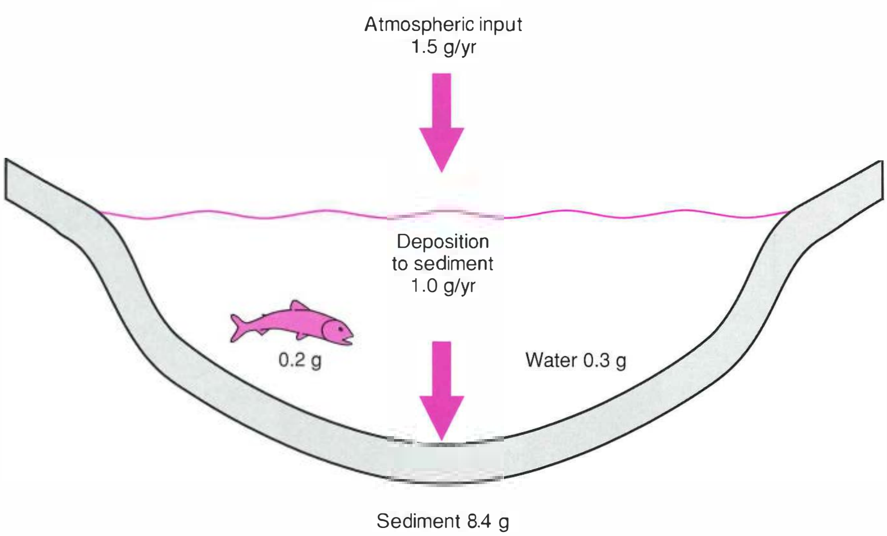


Figure 3 A mass balance of Hg in a Wisconsin seepage lake indicates that input from the atmosphere (15 µg/m² • yr) can easily account for all the mercury in fish. The uppermost centimeter of sediment contains 8.4 g of Hg as a result of particle settling.

the atmosphere and thereby minimize the accumulation of Hg by fish.

Future questions

The global atmospheric residence time for Hg is about one year, with a total atmospheric mass of 5–6 million kg. It is estimated that 30–55% of the input to the atmosphere is anthropogenic, with about half of that from fossil fuel combustion. The other major inputs to the atmosphere are open ocean release, which accounts for about one-third, and terrestrial processes, which account for the remainder (calculated by difference). Hg emissions from high-Hg coal are about 8 kg/trillion Btu. Thus, a 1300-MWe power plant burning eastern coal might emit 370 kg of Hg annually. Total worldwide annual emissions of Hg from coal-fired power plants have been estimated to range from 100,000 kg to 3 million kg. A considered estimate is that Hg from U.S. fossil fuel burning might amount to 5% of the global total.

Like global carbon dioxide, Hg is transported through the world's atmosphere, even though transport does not easily occur between hemispheric air masses. Important questions still exist about whether anthropogenic Hg entering the atmosphere is transported and deposited locally; undergoes long-range transport, like sulfur dioxide, to be deposited within several hundred kilometers; or enters the global transport cycle. EPRI initiatives on Hg emissions measurement (Generation and Storage Division) and atmospheric transport and transformation (Environment) will help answer these questions.

Transportation Program

The Chrysler Electric TEVan

by Gary Purcell, Customer Systems Division

ABSTRACT *Under EPRI sponsorship, Chrysler is building four proof-of-concept electric minivans; two are currently under test. Prototypes of the TEVan will be available to utilities within two years, and commercial production is anticipated within three years. By using advanced nickel-iron batteries in a lighter vehicle, the TEVan doubles the range of General Motors' G-Van, which is powered by conventional lead-acid batteries. The TEVan's extended range is expected to win it a larger market segment of the commercial van fleet, as well as a portion of the personal-vehicle market. The state-of-the-art TEVan has been designed for superior performance, traffic compatibility, and driver convenience.*

The Chrysler TEVan is a half-ton-payload electric minivan for carrying passengers or light cargo (Figure 1). As part of its electric vehicle (EV) research, EPRI has joined with Southern California Edison, the South Coast Air Quality Management District, and the U.S. Department of Energy to sponsor the development of the TEVan (RP2664-4).

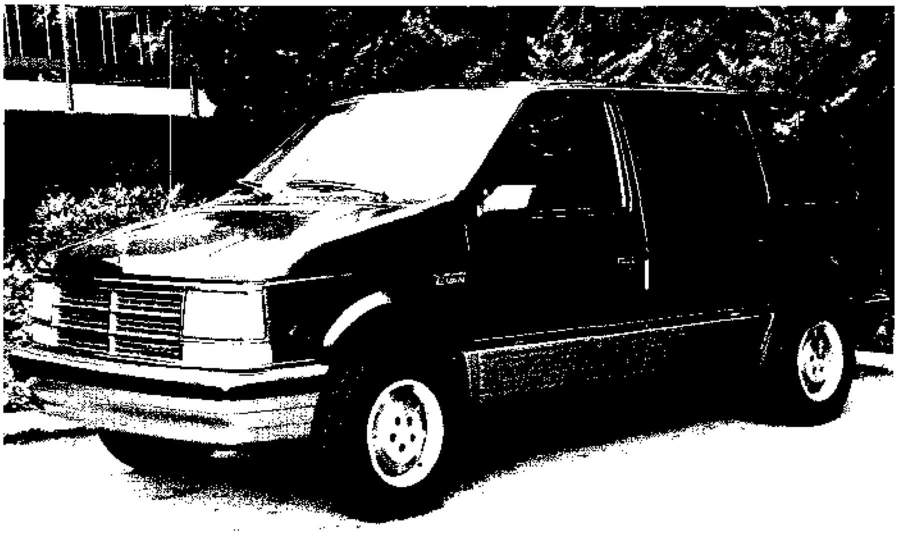
This electric minivan offers superior EV performance, including an urban driving range exceeding 120 miles, and can complement fleets and help increase the EV share of the commercial fleet market. The TEVan can also compete in the passenger fleet market—estimated at more than 5 million vehicles. It is expected that a more detailed market survey will be performed in the near future.

TEVan concept vehicles feature Chrysler's standard minivan design, used in the Dodge Caravan and Plymouth Voyager. In adapting this vehicle for electric drive, Chrysler's goal was to make it perform as well as conventional vehicles under normal driving conditions. Pentastar Electronics, a subsidiary of Chrysler, is building four proof-of-concept vehicles; two are currently under test. It is expected that Chrysler will maintain a hands-on interest in continued development of the vehicle over the next three years.

If testing of the proof-of-concept vehicles is successful, phase 2 of development will include the initiation of production engineering, and prototypes should become available to utilities for testing within two years. Full commercial production is expected in about three years, assuming federal safety standards and other industrial standards are met.

The key component in any EV is the propulsion battery. To be successful, an EV battery

Figure 1 The Chrysler TEVan. This electric minivan, the first geared toward passenger or light cargo use, is expected to be available to utilities in prototype form within the next two years.



must offer long life, provide reliable service, and require minimal maintenance. The lead-acid batteries in the early electric vans met some of these criteria but were limited by weight, energy storage capacity, power, and lifespan.

The TEVan concept vehicle is based on a 40-kWh, 180-V nickel-iron battery (Model NIF 200) developed by Eagle Picher Industries. This advanced battery gives the TEVan a superior energy storage capacity and a range of 120 miles per charge. Furthermore, in-vehicle testing at the Electric Vehicle Test Facility in Chattanooga, Tennessee, has demonstrated that the nickel-iron battery lasts longer than any other battery tested. The battery pack, comprising thirty 6-V modules, rests in an enclosed tray beneath the vehicle floor without intruding into the cabin area.

To minimize maintenance, a microprocessor-based battery management system automatically controls temperature, battery gas concentration, watering, and charging. The system also can rapidly diagnose individual cell failures. This management system will require visual battery inspection only once or twice a year.

The TEVan's two-speed transmission contributes to vehicle range, hill-climbing ability, and low-speed performance. Two gear ratios allow the motor to operate efficiently at high speeds, with maximum performance occurring at low speeds. A microprocessor in the motor controller operates the transmission automatically. In high gear this transmission has an efficiency of 98%, compared with 95% and 90% for manual and automatic transmissions, respectively, in a comparable conventional vehicle. An electrically driven vacuum pump operates the standard, vacuum-assisted power brakes. The mechanical braking system is supplemented by regenerative braking, which can increase the vehicle range by up to 15%. The hydraulic steering unit is also powered electrically.

It should be noted that the vehicle design allows for the use of lead-acid batteries if necessary, and one of the proof-of-concept vehicles will rely on a lead-acid battery, although range performance will thus be diminished. At present, the nickel-iron batteries are assembled manually, but it is expected that a pilot plant for these batteries will be built in the same timeframe as the electric vehicle.

New Contracts

Project	Funding/ Duration	Contractor/EPRI Project Manager
Business Management		
Seminar Development: Application of Decision Analysis Tools to Utility Investment Planning (RP2807-4)	$99,500 12 months	Applied Decision Analysis, Inc./*S. Chapel*
Electrical Systems		
Teleoperator for Operations, Maintenance, and Construction Using Advanced Technology (TOMCAT) Market Study Research (RP1497-4)	$75,000 5 months	Foster-Miller Associates, Inc./*H. Mehta*
Transmission Research at High Voltage Transmission Research Center (RP2472-6)	$14,000,000 60 months	General Electric Co./ *J. Hall*
Integration of Database Procedures for Integrated Communications Systems (RP2949-5)	$495,100 9 months	Honeywell, Inc./ *W. Malcolm*
Multiarea Unit Commitment With Security Evaluation (RP4000-10)	$279,000 35 months	University of Oklahoma/ *R. Adapa*
Microscopic Probes of High-Temperature Superconductivity (RP7911-15)	$59,200 24 months	Virginia Commonwealth University/*M. Rabinowitz*
Environment		
Body Burden Models (RP2310-7)	$72,700 7 months	CH2M-Hill/*A. Silvers*
The Ability of Subsoils to Attenuate Metals in Coal Pile Leachates (RP2485-18)	$78,500 21 months	University of Wisconsin/ *M. Elrashidi*
Assessment of Children's Long-Term Exposure to Magnetic Fields (RP2966-4)	$193,200 17 months	Geomet Technologies, Inc./*S. Sussman*
Assessment of Children's Long-Term Exposure to Magnetic Fields (RP2966-6)	$175,600 10 months	Enertech Consultants/ *S. Sussman*
Relationships Between Sulfur Dioxide–Induced Bronchoconstriction and Daily Activities in Asthmatic Subjects (RP3009-3)	$281,500 18 months	University of California, Los Angeles/*W. Weyzen*
Exploratory Research		
Exploratory Research on Flow in Fluidized Beds (RP8006-16)	$185,700 36 months	University of Bradford/ *J. Stallings*
Particulate Mot'on in Wall Turbulent Flow (RP8006-17)	$348,000 36 months	University of California, Santa Barbara/ *J. Maulbetsch*
New Architectures for Superconductive Power Systems (RP8009-3)	$75,000 16 months	Texas A&M Research Foundation/*R. Iveson*
Generation and Storage		
Preliminary Assessment of High-Temperature Steam Topping Turbine (RP1403-44)	$157,400 12 months	Solar Turbines, Inc./ *J. Bartz*
Guidelines for the Use of FRP in Utility FGD Systems (RP1871-22)	$183,200 13 months	Fiberglass Structural Engineering, Inc./*C. Dene*
Alloy Development for Use in Superheaters of Coal Gasification Plants (RP2048-10)	$147,500 22 months	IHI Company, Ltd./ *W. Bakker*
IGCC/Methanol Coproduction Study (RP2146-8)	$234,800 11 months	Bechtel Group, Inc./ *W. Weber*
Fines-Processing Options for British Gas–Lurgi Coal Gasifier (RP2525-22)	$108,000 6 months	Bechtel Group, Inc./ *M. Epstein*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Algorithm Development for Steam Temperature Control in Fossil Plants (RP2710-13)	$150,000 13 months	Honeywell, Inc./ *S. Divakaruni*
Engineer-of-Record Services (RP2870-8)	$167,800 18 months	Bechtel Power Corp./ *G. Cook*
PM Firing System Applicability/Economic Study (RP2916-11)	$174,600 12 months	Combustion Engineering, Inc./*D. Eskinazi*
Support for EPRI High-Concentration Photovoltaic Development Program (RP2948-21)	$120,000 12 months	Southern Electric International, Inc./ *J. Bigger*
Development of H_2O_2/Ozone Treatment for Town Gas Agglomeration Tailings (RP2991-4)	$104,800 6 months	Arctech, Inc./*C. Kulik*
Utility HAT Cycle Evaluation (RP2999-7)	$327,600 12 months	Fluor Engineers, Inc./ *M. Gluckman*
Development of Natural Gas–Fueled IMHEX MCFC (RP3058-3)	$600,700 12 months	M-C Power Corp./ *R. Goldstein*
Transportable Pulse-Jet Baghouse Field Testing—Site No. 1 (RP3083-5)	$152,000 22 months	ADA Technologies, Inc./ *R. Chang*
Hydro-Relicensing Research Project (RP3113-2)	$232,000 40 months	Richard Hunt Associates/ *C. Sullivan*
Nuclear Power		
Modeling of Stress Corrosion Cracking of Low-Alloy Steel (RPC102-1)	$50,900 4 months	General Electric Co./ *R. Pathania*
Steam Generator Tube Plugging Criteria and Burst Test Results (RPS404-25)	$105,000 6 months	Framatome/*C. Williams*
Loop Testing of Alternative Amines for All-Volatile Treatment Control (RPS409-11)	$640,600 21 months	Calgon Corp./*T. Passel*
Technical Review of Polyamide-Insulated Wire in Nuclear Power Plants (RP1707-43)	$51,000 5 months	ERC Environmental and Energy Services Co./ *G. Sliter*
Modular High-Temperature Gas Reactor Evaluation (RP2079)	$59,900 8 months	Yankee Atomic Electric Co./*E. Rodwell*
BWR Full-System Decontamination Study (RP2296-22)	$628,900 16 months	General Electric Co./ *C. Wood*
PWR Reactor Coolant System (RP2643-29)	$198,400 17 months	Babcock & Wilcox Co./ *J. Byron*
PWR Passive Plant Heat Removal Assessment (RP2660-51)	$199,800 13 months	MPR Associates/ *J. Yedidia*
Ultrasonic Wave Propagation in RPV Cladded Interfaces (RP2687-8)	$50,100 4 months	Weidlinger Associates/ *M. Avioli*
Spent-Fuel Canister Compatibility Study (RP2717-12)	$74,500 8 months	Nutech International/ *R. Lambert*
Limit Value Approach for Estimating BE Code Uncertainties in LOCA Calculat'ons and Plant Applications (RP2956-2)	$396,700 34 months	Combustion Engineering, Inc./*S. Kalra*
EPRI–CRIEPI RPV Database and Analysis (RP2975-13)	$167,800 4 months	Tenera LP/*T. Griesbach*
Implementation of Effective Dose Equivalent for External Radiation (RP3099-4)	$516,600 16 months	Battelle, Pacific Northwest Laboratories/*P. Robinson*
Development of Computer Code for Site Response to Finite Earthquake Source (RP3102-2)	$71,000 6 months	Woodward-Clyde Consultants/*J. Schneider*
Reduction of Maintenance Personnel Errors (RP3111-1)	$203,000 11 months	Anacapa Sciences, Inc./ *J. O'Brien*

New Technical Reports

Requests for copies of reports should be directed to Research Reports Center, P.O. Box 50490, Palo Alto, California 94303; (415) 965-4081. There is no charge for reports requested by EPRI member utilities, U.S. universities, or government agencies. Reports will be provided to nonmember U.S. utilities only upon purchase of a license, the price for which will be equal to the price of EPRI membership. Others in the United States, Mexico, and Canada pay the listed price. Overseas price is double the listed price. Research Reports Center will send a catalog of EPRI reports on request. To order one-page summaries of reports, call the EPRI Hotline, (415) 855-2411.

CUSTOMER SYSTEMS

Electric Alternatives to Commercial Cogeneration

CU-6606 Proceedings (RP2983-1); $100
Contractor: Barakat, Howard & Chamberlin, Inc.
EPRI Project Manager M. Blatt

Optimizing Energy Use in the Process Industries, Vols. 1–4

CU-6645 Final Report (RP2783-8); Vol. 1, $100; Vol. 2, $300; Vol. 3, $300; Vol. 4, $300
Contractor: ICI-Tensa Services
EPRI Project Managers: A. Pavone, K. Amarnath

Commercial Heat Pump Water Heaters: Applications Handbook

CU-6666 Final Report (RP2958-8); $100
Contractor: D. W. Abrams, P.E. & Associates
EPRI Project Manager: K. Johnson

Inventory of Utility-Sponsored Indoor Air Quality Research

CU-6684 Final Report (RP2034-25); $100
Contractor: GEOMET Technologies, Inc.
EPRI Project Manager J. Kesselring

Assessment of U.S. Electric Vehicle Programs With AC Powertrains

CU-6685 Final Report (RP2861-2); $100
Contractor: Booz, Allen & Hamilton, Inc.
EPRI Project Manager: B. Banerjee

ELECTRICAL SYSTEMS

Advanced Float-Zone Silicon Development

EL-6599 Final Report (RP2737-4); $25
Contractor: Westinghouse R&D Center
EPRI Project Manager: H. Mehta

Long-Term Dynamics Simulation: Modeling Requirements

EL-6627 Final Report (RP2473-22); $32.50
Contractor: Ontario Hydro
EPRI Project Manager: D. Curtice

Power System Operations: Research Needs and Priorities

EL-6659 Proceedings (RP2473-35); $32.50
Contractor: Barakat, Howard & Chamberlin, Inc.
EPRI Project Manager: D. Curtice

Small Signal Stability Analysis Program Package: Version 2.0 User Manual

EL-6678 Final Report (RP2447-1); $32.50
Contractor: Ontario Hydro
EPRI Project Manager: M. Lauby

ENVIRONMENT

A Plant-Growth Stress Model: Conceptual Model and Development Plan

EN-6639 Final Report (RP2365-1); $25
Contractor: Systech Engineering, Inc.
EPRI Project Manager: R. Goldstein

Status of Subregional and Mesoscale Models, Vol. 1: Air Quality Models

EN-6649 Final Report (RP2434-6); $32.50
Contractor: Bechtel Environmental, Inc.
EPRI Project Manager: P. Mueller

Extremely Low Frequency Electric and Magnetic Fields and Cancer: A Literature Review

EN-6674 Final Report (RP2965-12); $32.50
Contractor: Information Ventures, Inc.
EPRI Project Manager: C. Rafferty

EXPLORATORY RESEARCH

Biomimetic Catalysis of Light Hydrocarbons to Their Associated Alcohols

ER-6663 Interim Report (RP8003-3); $25
Contractor: Lawrence Berkeley Laboratory
EPRI Project Manager: S. Yunker

Reaction Mechanisms in Liquid-Phase Methanol Synthesis

ER/GS-6715 Interim Report (RP8003-11); $32.50
Contractor: University of Akron
EPRI Project Manager: C. Kulik

GENERATION AND STORAGE

AFBC Conversion at Northern States Power Company, Vol. 4: Construction

CS-5501 Final Report (RP2628-3); $40
Contractor: Stone & Webster Engineering Corp.
EPRI Project Managers: S. Tavoulareas, J. Stallings

Guide for Developing a Hydro Plant Relicensing Strategy, Vol. 2: Strategy Development

AP-6038 Final Report (RP2694-5); $200
Contractor: Richard Hunt Associates
EPRI Project Manager: J. Birk

Technology Assessments for Advanced Fossil Power Systems

GS-6165 Special Report (RP2387); $25
Contractor: Bevilacqua-Knight, Inc.
EPRI Project Manager: A. Cohn

The TVA Moving-Manifold Targeted-Chlorination System: Second Field Demonstration

GS-6253 Final Report (RP2300-10); $32.50
Contractor: Battelle, Columbus Division
EPRI Project Manager: W. Chow

Cooling-Tower Performance Prediction and Improvement, Vols. 1 and 2

GS-6370 Final Report (RP2113); Vol. 1, $1000; Vol. 2, $1000
Contractors: Battelle, Pacific Northwest Laboratories; Environmental Systems Corp., Tennessee Valley Authority, Engineering Laboratory
EPRI Project Manager: J. Bartz

Shell Coal Gasification Project (SCGP-1): Design and Construction Phase

GS-6372 Interim Report (RP2695-1); $25
Contractor: Shell Development Co.
EPRI Project Manager: N. Stewart

Shell Coal Gasification Project (SCGP-1): Shakedown and Demonstration Phases

GS-6373 Interim Report (RP2695-1); $25
Contractor: Shell Development Co.
EPRI Project Manager: N. Stewart

Guidelines for Prevention of Cavitation in Centrifugal Feedpumps

GS-6398 Final Report (RP1884-10); $1500
Contractor: Sulzer Brothers Ltd.
EPRI Project Managers: T. McCloskey, S. Pace

Use of Ash in Highway Construction: Delaware Demonstration Project

GS-6540 Final Report (RP2422-4); $32.50
Contractors: Delmarva Power & Light Co.; VFL Technology Corp.
EPRI Project Manager: D. Golden

Solano MOD-2 Wind Turbine Operating Experience Through 1988

GS-6567 Final Report (RP1590-6); $25
Contractor: Pacific Gas and Electric Co.
EPRI Project Manager: J. Schaefer

FGD Damper Guidelines, Vols. 1 and 2

GS-6569 Final Report (RP2250-1); Vol. 1, $500; Vol. 2, $500
Contractor: Black & Veatch Engineers-Architects
EPRI Project Manager: P Radcliffe

Methods for Assessing the Stability and Compatibility of Residual Fuel Oils

GS-6570 Final Report (RP2527-1); $32.50
Contractor: National Institute for Petroleum and Energy Research
EPRI Project Manager: W. Rovesti

Recuperators for Compressed-Air Energy Storage Plants

GS-6571 Final Report (RP2676-1); $32.50
Contractor: Gibbs & Hill, Inc.
EPRI Project Manager: R. Pollak

Status of Solar-Thermal Electric Technology

GS-6573 Final Report (RP2003-9); $47.50
Contractor: H. G. H. Enterprises
EPRI Project Manager: E. DeMeo

Model Validation: Cooling-Tower Performance
GS-6574 Final Report (RP2113-8); $25
Contractor: Pacific Gas and Electric Co.
EPRI Project Manager: J. Bartz

Trace Elements in Coal and Coal Wastes
GS-6575 Interim Report (RP1400-6, -11); $200
Contractor: Kaiser Engineers, Inc.
EPRI Project Managers: J. Hervol, C. Harrison

Molten Salt Solar-Electric Experiment, Vols. 1 and 2
GS-6577 Final Report (RP2302-2); Vol. 1, $40; Vol. 2, $55
Contractor: McDonnell Douglas Astronautics Co.
EPRI Project Manager: E. DeMeo

1988 Interorganizational Workshop on Future Utility SO_2 Emissions
GS-6578 Special Report; $25
EPRI Project Manager: C. McGowin

The Application of Molecular Genetics Techniques to Bioremediation Processes
GS-6591 Final Report (RP2655-28); $32.50
Contractor: Susan Alpert
EPRI Project Manager: S. Yunker

Planned Outage Reduction for Combustion Turbines and Combined-Cycle Plants
GS-6595 Final Report (RP2831-1); $25
Contractor: Creole Production Services, Inc.
EPRI Project Manager: R. Frischmuth

Rainbow Test of Advanced Coatings for Gas Turbine Blades and Vanes
GS-6596 Final Report (RP2465-1); $5200
Contractor: Solar Turbines, Inc.
EPRI Project Manager: R. Frischmuth

Superclean Steel Development: Status Report
GS-6610 Interim Report (RP1403-32); $32.50
Contractor: Daedalus Associates, Inc.
EPRI Project Manager: R. Jaffee

Superclean Steel Development: A Guide for Utility Use
GS-6612 Final Report (RP1403-32); $25
Contractor: Daedalus Associates, Inc.
EPRI Project Manager: R. Jaffee

Compressed-Air Energy Storage Using Hard-Rock Geology: Test Facility and Results, Vols. 1 and 2
GS-6620 Final Report (RP1791-13); Vol. 1, $70; Vol. 2, $77.50
Contractor: Société Electrique de l'Our S.A.
EPRI Project Manager: R. Schainker

Assessment of Circulating Atmospheric Fluidized-Bed Combustion Technology for Utility Applications
GS-6621 Final Report (RP1180-17); $40
Contractor: United Engineers & Constructors, Inc.
EPRI Project Manager: S. Tavoulareas, J. Stallings

Laboratory Characterization of Advanced SO_2 Control By-Products: Dry Sodium and Calcium In-Duct Injection Wastes
GS-6622 Final Report (RP2708-1); $40
Contractor: ICF Technology, Inc.
EPRI Project Manager: D. Golden

Photovoltaic Operation and Maintenance Evaluation
GS-6625 Final Report (RP1607-5); $40
Contractor: R. Lynette & Associates, Inc.
EPRI Project Manager: J. Schaefer

1988 EPRI Heat-Rate Improvement Conference
GS-6635 Proceedings (RP1711-6); $500
Contractor: Sargent & Lundy
EPRI Project Manager: R. Leyse

Strategic Assessment of Storage Plants, Economic Studies: Benefits Under a Regulated Versus Deregulated Utility
GS-6646 Final Report (RP128-15); $32.50
Contractor: Polydyne, Inc.
EPRI Project Manager: R. Schainker

Testing of Illinois Coal in a Circulating Fluidized Bed
GS-6664 Final Report (RP718-11); $25
Contractor: Babcock & Wilcox Co.
EPRI Project Managers: T. Boyd, E. Petrill

A Coal Gasification–Combined-Cycle Power Plant With Methanol Storage
GS/ER-6665 Final Report (RP8000-5); $40
Contractor: Stanford University
EPRI Project Manager: M. Gluckman

Pumped-Storage Planning and Evaluation Guide
GS-6669 Final Report (RP1745-30); $500
Contractor: Harza Engineering Co.
EPRI Project Manager: C. Sullivan

Compressed-Air Energy Storage Field Test Using the Aquifer at Pittsfield, Illinois
GS-6671 Final Report (RP1791-15); $55
Contractor: PB–KBB, Inc.
EPRI Project Manager: B. Mehta

Review of Research on Coal-Handling Characteristics
GS-6677 Interim Report (RP1400-6); $400
Contractor: Kaiser Engineers, Inc.
EPRI Project Managers: C. Harrison, J. Hervol

Potential Economic Benefits of Battery Storage to Electrical Transmission and Distribution Systems
GS-6687 Final Report (RP1084-35); $32.50
Contractor: Power Technologies, Inc.
EPRI Project Manager: B. Louks

Carrisa Plains Photovoltaic Power Plant: 1984–1987 Performance
GS-6689 Final Report (RP1607-2); $25
Contractor: Pacific Gas and Electric Co.
EPRI Project Manager: J. Schaefer

Application of Oil Agglomeration Technology for Coal Upgrading
GS-6691 Final Report (RP2147-10); $32.50
Contractor: Alberta Research Council
EPRI Project Manager: L. Atherton

The Market for Fuel Cell Power Plants Within Municipally Owned Utilities
GS-6692 Final Report (RP1677-16); $40
Contractor: Technology Transition Corp.
EPRI Project Managers: E. Gillis, D. Rastler

Photovoltaic System Performance Assessment for 1988
GS-6696 Final Report (RP1607-6); $32.50
Contractor: Southwest Technology Development Institute
EPRI Project Manager: J. Schaefer

Remediation Technologies for Organics Contamination
GS-6700 Final Report (RP2991-1); $32.50
Contractor: Mill Creek Co.
EPRI Project Manager: C. Kulik

Sodium/Sulfur Battery Storage: Integrated Generation Portfolio Analysis and Commercialization Strategy
GS-6704 Final Report (RP128-15); $32.50
Contractor: Polydyne. Inc.
EPRI Project Manager: R. Weaver

NUCLEAR POWER

Below Regulatory Concern (BRC) Owners Group: A Comparison of the EPA Generic Cost-Benefit Analysis With an Industry-Specific Analysis
NP-5673 Final Report (RPB101-11); $25
Contractor: Rogers and Associates Engineering Corp.
EPRI Project Manager: P. Robinson

Determination of Thermodynamic Data for Modeling Corrosion, Vols. 1 and 2
NP-5708 Final Report (RPS407-1); Vol. 1, $32.50; Vol. 2, $32.50
Contractor: Brigham Young University
EPRI Project Manager: J. Paine

Guidelines for the Technical Evaluation of Replacement Items in Nuclear Power Plants (NCIG-11)
NP-6406 Final Report (RPQ101-8); $32.50
Contractor: CYGNA Energy Services
EPRI Project Manager: W. Bilanin

Numerical Simulation of Bubbly Flow
NP-6557 Final Report (RP888-1); $62.50
Contractor: JAYCOR
EPRI Project Manager: G. Srikantiah

The 1986 Leroy, Ohio, Earthquake: Performance of Power and Industrial Facilities
NP-6558 Final Report (RP2849-3); $25
Contractor: Stevenson and Associates
EPRI Project Manager: R. Kassawara

Voice Communication Systems Compatible With Respiratory Protection

NP-6559 Final Report (RP2705-7); $25
Contractor: ARINC Research Corp.
EPRI Project Manager: J. O'Brien

Operation of the EPRI Nondestructive Evaluation Center: 1988 Annual Report

NP-6565 Interim Report (RP1570-2); $32.50
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: G. Dau

The Appendix "K" Relief Workshop

NP-6568 Proceedings (RP2956); $200
EPRI Project Manager: S. Kalra

The Effect of Improved Water Chemistry on Corrosion Cracking of BWR Piping: Workshop Proceedings

NP-6585 Proceedings (RP2006-17); $47.50
Contractor: GE Nuclear Energy
EPRI Project Manager: R. Pathania

Microanalysis of TMI-2 Core Debris Samples

NP-6590 Final Report (RP2056-4); $25
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: R. Lambert

The New Zealand Earthquake of March 2, 1987: Effects on Electric Power and Industrial Facilities

NP-6593 Final Report (RP2848-6); $40
Contractor: EQE Engineering
EPRI Project Manager: R. Kassawara

BWR Reactor Vessel In-Service Inspection Database

NP-6601 Final Report (RP2057-7); $32.50
Contractor: Science Applications International Corp.
EPRI Project Manager: S. Liu

Assessment of Scaling Uncertainties for PWR Plant Large-Break LOCA Analysis

NP-6602 Final Report (RP2639-2); $25
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: S Kalra

Vaporization of Strontium, Barium, Lanthanum, and Uranium From Mixtures of Urania, Zirconia, Steel, and Concretes at 2150 K and 2400 K

NP-6613 Final Report (RP2136-1); $25
Contractor: Argonne National Laboratory
EPRI Project Manager: R. Ritzman

ARROTTA–HERMITE Code Comparison

NP-6614 Final Report (RP2941-7); $32.50
Contractor: Combustion Engineering, Inc.
EPRI Project Manager: L. Agee

Finite-Element Analysis of Flawed and Unflawed Pipe Tests

NP-6615 Final Report (RP2756-2); $25
Contractor: ANATECH Research Corp.
EPRI Project Managers: D. Norris, J. Gilman

Plant Tests of Surface Preconditioning for Steam Generators

NP-6616 Interim Report (RP2758-2); $25
Contractor: Radiological & Chemical Technology
EPRI Project Manager: C. Wood

Electropolishing Qualification Program for PWR Steam Generator Channel Heads

NP-6617 Final Report (RP2758-6); $40
Contractor: Westinghouse Electric Corp.
EPRI Project Managers: C. Spalaris, C. Wood

The Nature and Behavior of Particulates in PWR Primary Coolant

NP-6640 Final Report (RP1445-4); $32.50
Contractor: AEA Technology, Winfrith
EPRI Project Manager: C. Wood

Effect of Coolant Chemistry on PWR Radiation Transport Processes, Vols. 1–3

NP-6657 Final Report (RP2295-2); Vol. 1, $32.50; Vol. 2, $25; Vol. 3, $32.50
Contractor: United Kingdom Atomic Energy Authority
EPRI Project Manager: C. Wood

Application of the EPRI Simulator Qualification Methodology to the Bugey Simulator

NP-6658 Final Report (RP3107); $47.50
Contractor: Electricité de France
EPRI Project Manager: J. Sursock

Cognitive Correlates of Ultrasonic Inspection Performance

NP-6675 Topical Report (RP2705-9); $32.50
Contractor: Anacapa Sciences, Inc.
EPRI Project Managers: H. Parris, J. O'Brien

Guidebook for Maintenance Proficiency Testing

NP-6679 Final Report (RP2705-10); $40
Contractor: Anacapa Sciences, Inc.
EPRI Project Managers: H. Parris, J. O'Brien

Guidelines for Nuclear Plant Response to an Earthquake

NP-6695 Final Report (RP2848-21): $25
Contractor: MPR Associates, Inc.
EPRI Project Manager: R. Kassawara

Analysis of Zircaloy Oxide Thickness Data From PWRs

NP-6698 Final Report (RP1250-18); $25
Contractor: S. M. Stoller Corp.
EPRI Project Manager: O. Ozer

Progress in Radiation Control Technology

NP-6708 Final Report (RP2758); $25
EPRI Project Managers: H. Ocken, C. Wood

UTILITY PLANNING

Service Design in the Electric Power Industry

P-6543 Interim Report (RP2801-1); $40
Contractor: Pricing Strategy Associates
EPRI Project Manager: H. Chao

New Computer Software

The Electric Power Software Center (EPSC) provides a single distribution center for computer programs developed by EPRI. The programs are distributed under license to users. EPRI member utilities, in paying their membership fees, prepay all royalties. EPRI software is not available to nonmember U.S. utilities. No royalties are charged to nonutility public service organizations in the United States, including government agencies, universities, and other tax-exempt organizations. Industrial organizations are required to pay royalties. Basic support in installing the codes is available at no charge from EPSC; however, a consulting fee may be charged for extensive support.

For more information about EPSC and licensing arrangements, EPRI member utilities, government agencies, universities, and other tax-exempt organizations should contact the Electric Power Software Center, Power Computing Co., 1930 Hi Line Drive, Dallas, Texas 75207; (214) 655-8883. Industrial organizations should contact EPRI's Manager of Licensing, P.O. Box 10412, Palo Alto, California 94303; (415) 855-2866.

CHIRON: Prediction of Failed Fuel Rods

Version 1.1 (IBM PC)
Contractor: S. Levy, Inc.
EPRI Project Manager: Peter Rudling

COGENADVISOR: Expert System for Providing Guidance on Cogeneration and Electric Alternatives

Version 1.0 (IBM PC); CU-6450-CCML
EPRI Project Managers: David Cain, Jane Choi, Hans Gransell, William Smith, Morton Blatt

COMTECH: Commercial Technologies Screening Model

Version 1.0 (IBM PC)
Contractor: Regional Economic Research
EPRI Project Manager: Karl Johnson

CONTRACTMIX: Fuel Contract Mix Decision Analysis Methodology

Version 2.0 (IBM PC); P-5243-CCM
Contractor: Decision Focus, Inc.
EPRI Project Manager: Howard Mueller

EGEAS: Electric Generation Expansion Analysis System

Version 4.1 (IBM, PRIME); EL-2561
Contractor: Stone & Webster
EPRI Project Manager: Giora Ben-Yaacov

EQHAZARD: Probabilistic Seismic Hazard Analysis

Version 1.0 (CDC, IBM); NP-4726A
Contractor: Jack R. Benjamin & Associates
EPRI Project Manager: J. Carl Stepp

ETMSP: Extended Transient–Midterm Stability Package
Version 2.0 (VAX); EL-2000-CCM
Contractors: Arizona Public Service Co., Arizona State University; Boeing Computer Services, Inc.; ESCA Corp.; Ontario Hydro; Systems Control, Inc.
EPRI Project Manager: Mark Lauby

IGSCC ADVISOR: Expert System for Assessing Intergranular Stress Corrosion Cracking in Austenitic Stainless Steel Piping
Version 1.0 (IBM PC); NP-6579-CCML
Contractor: Structural Integrity Associates, Inc.
EPRI Project Managers: David Cain, Melvin Lapides

LOADSYN: Load Modeling for Power Flow and Transient Stability Computer Studies
Version B-002 (IBM PC-OS/2); EL-5003-CCM
Contractor: General Electric Co.
EPRI Project Manager: Dave Curtice

MYGRT: Migration of Solute in the Subsurface Environment Capacity in Electrical Power System Planning
Version 2.0 (IBM PC); EN-6531
Contractor: Tetra Tech, Inc.
EPRI Project Manager: Ishwar Murarka

RISKMIN: An Approach to Risk Evaluation in Electric Resource Planning
Version 1.0 (IBM PC); EL-5851
Contractor: Public Service Electric & Gas Co.
EPRI Project Manager: Giora Ben-Yaacov

SLIC2: Steam Line Inspection Code
Version 0.0 (IBM PC)
Contractor: Failure Analysis Associates
EPRI Project Manager: Barry Dooley

STARRS: Expert Analytical Tool for Assessing PWR Steam Generator Tube Rupture Events
Version 1.0 (IBM PC); NP-6490-CCML
Contractor: Science Applications International Corp.
EPRI Project Managers: David Cain, Jane Choi, Satya Pal Kalra

SURIS: DSM Survey Information Survey
Version 1.0 (IBM PC)
Contractor: Battelle
EPRI Project Manager: Phil Hanser

TLWorkstation: Integrated Transmission Line Software
Version 2.0 (IBM PC); EL-6420-L
Contractor: Power Computing Co.
EPRI Project Manager: Richard Kennon

VIPRE-01: A Thermal Hydraulic Analysis Code
Version MOD2 (CDC, IBM); NP-2511-CCM
Contractor: Battelle, Pacific Northwest Laboratories
EPRI Project Managers: Joe Naser, Govinda Srikantiah

CALENDAR

For additional information on the meetings listed below, please contact the person indicated.

JUNE

11–13
Applications of Power Production Simulation
Washington, D.C.
Contact: Mark Lauby, (415) 855-2304

18–22
High-Voltage Transmission Line Design: DCLINE and ENVIRO
Lenox, Massachusetts
Contact: James Hall, (415) 855-2305

19
ESCORE Users Group Meeting
Chicago, Illinois
Contact: Odelli Ozer, (415) 855-2089

19–21
Fuel Science Annual Meeting
Palo Alto, California
Contact: Howard Lebowitz, (415) 855-2517

20–22
Diesel Generator Operation, Maintenance, and Testing
Orlando, Florida
Contact: Harvey Wyckoff, (415) 855-2393

25–29
Control Center Operator (Dispatcher) Training Simulator
Philadelphia, Pennsylvania
Contact: David Curtice, (415) 855-2832

JULY

16–17
RCM Users Group Meeting
Location to be determined
Contact: Gordon Allen, (415) 855-2219

24–26
Slagging Combustion Interest Group Meeting
Edmonton, Canada
Contact: Angelos Kokkinos, (415) 855-2494

24–27
Advanced Machinery Vibration Diagnostics
Eddystone, Pennsylvania
Contact: Sam Haddad, (415) 855-2172

29–August 3
International Conference: Indoor Air Quality and Climate
Toronto, Canada
Contact: Cary Young, (408) 755-4301

31–August 3
Workshop: Digital Signal Processing for NDE and Plant Maintenance
Charlotte, North Carolina
Contact: Jim Lang, (415) 855-2038, or Ramesh Shankar, (704) 547-6127

AUGUST

7–10
Power Plant Life Assessment and Stress Monitoring
Eddystone, Pennsylvania
Contact: Steve Gehl, (415) 855-2770, or Vis Viswanathan, (415) 855-2450

20–23
Power Plant Valve Symposium
Charlotte, North Carolina
Contact: Jim Lang, (415) 855-2038

28–30
Generator Diagnostics
Eddystone, Pennsylvania
Contact: Murthy Divakaruni, (415) 855-2409

28–30
International Conference: Measuring Waterborne Trace Substances
Baltimore, Maryland
Contact: Winston Chow, (415) 855-2868

SEPTEMBER

5–6
Workshop: Modeling Ground Motion Close to Large Earthquakes
Palo Alto, California
Contact: John Schneider, (415) 855-7921

10–14
Seminar: PCB/Dioxin 1990
Bayreuth, Germany
Contact: Gil Addis, (415) 855-2286

17–19
Seminar: Service Water Systems Reliability Improvement
Atlanta, Georgia
Contact: Norris Hirota, (415) 855-2084

18–20
Conference: Condenser Technology
Boston, Massachusetts
Contact: John Tsou, (415) 855-2220

18–21
Machinery Balancing and Alignment
Charlotte, North Carolina
Contact: Tom McCloskey, (415) 855-2655

CONTINUED

CALENDAR CONTINUED

19–21
Effects of Coal Quality on Power Plants
St. Louis, Missouri
Contact: Arun Mehta, (415) 855-2895

24–26
Railroad, Pipeline, and Transmission Line Compatibility
Haslet, Texas
Contact: Jim Hall, (415) 855-2305

25–27
Diesel Generator Diagnostics
Charlotte, North Carolina
Contact: Sam Haddad, (415) 855-2172

25–27
Use of Less-Volatile Amines in PWR Secondary-Side Water Treatment
Tampa, Florida
Contact: Tom Passell, (415) 855-2070

27–28
Overhead Transmission Line Optimization: TLOPWT
Haslet, Texas
Contact: Dick Kennon, (415) 855-3211

OCTOBER

2–4
Electric Motor Diagnostics
Eddystone, Pennsylvania
Contact: Jim Edmonds or J C. White, (415) 855-2291

9–11
Noncombustion Waste
New Orleans, Louisiana
Contact: Mary McLearn, (415) 855-2487

10–11
Workshop: Feedwater Heater Maintenance Technology
Eddystone, Pennsylvania
Contact: John Tsou, (415) 855-2220

15–17
Incipient Failure Detection: Predictive Maintenance for the 1990s
Philadelphia, Pennsylvania
Contact: Sam Haddad, (415) 855-2172, or John Scheibel, (415) 855-2850

15–17
Information Technology for the Power Industry: CD ROM and Laser Disks for PCs
Washington, D.C.
Contact: Joe Judy, (415) 855-8936

16–18
Fuel Supply Seminar
Memphis, Tennessee
Contact: Howard Mueller, (415) 855-2745

17–19
AIRPOL/90 Seminar: Solving Corrosion Problems in Air Pollution Control Equipment
Louisville, Kentucky
Contact: Paul Radcliffe, (415) 855-2720

23–24
Thermography
Location to be determined
Contact: Gordon Allen, (415) 855-2219, or Mike Downs, (415) 855-7940

30–November 2
Vibration Testing and Analysis
Eddystone, Pennsylvania
Contact: Sam Haddad, (415) 855-2172

31–November 1
1990 Fuel Oil Utilization Workshop
Washington, D.C.
Contact: William Rovesti, (415) 855-2519

NOVEMBER

1–2
T&D Cable Installation
St. Petersburg, Florida
Contact: Tom Rodenbaugh, (415) 855-2306

5–9
Fireside Performance of Coal-Fired Boilers
Eddystone, Pennsylvania
Contact: Bob Leyse, (415) 855-2995

12–14
Main Coolant Pump Monitoring and Diagnostics
Eddystone, Pennsylvania
Contact: Joe Weiss, (415) 855-2751

14–16
1990 Electric Utility Market Research Symposium
Atlanta, Georgia
Contact: Thom Henneberger, (415) 855-2885

27–29
Fossil Power Plant Cycling
Washington, D.C.
Contact: James Valverde, (415) 855-7998

DECEMBER

4–5
Air-Operated-Valve Diagnostics
Eddystone, Pennsylvania
Contact: Joe Weiss, (415) 855-2751

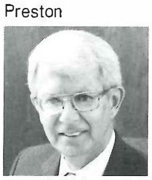
Authors and Articles


Gellings


Yau


Harrison


Preston


Fremling


Touchton

New Push for Energy Efficiency (page 4) was written by Leslie Lamarre, science writer, with technical guidance from two staff members of EPRI's Customer Systems Division.

Clark Gellings, division director, has been with EPRI since 1982, first as manager of a demand and conservation program and later as senior program manager for demand-side planning. He became division director in 1989. He was formerly with Public Service Electric & Gas for 14 years, holding several positions in the areas of marketing, rates, and load management.

Timothy Yau, division manager of strategic planning, came to his position early in 1989 after 11 years in system studies—the incorporation of new technologies, such as fuel cells and energy storage, into utility system planning and operations. Before that he was a project manager in the Electrical Systems Division. Yau joined EPRI in 1974 after five years in regional transmission planning for Pacific Gas and Electric. ■

Henry Linden Takes a Look at Electricity (page 18) looks at the world of energy technology from the viewpoint of a man who has spent more than 40 years teaching, promoting, and managing gas technology R&D. The founding president of the Gas Research Institute, Linden is now a member of EPRI's Advisory Council. Feature editor Ralph Whitaker wrote the article after interviewing Linden. ■

CQ Inc.: Now Open for Business (page 24) was written by David Boutacoff, *Journal* feature writer, who used information from several sources at EPRI and its new subsidiary, CQ Inc.

Clark Harrison, named president of CQ Inc. as it started operations this March, had managed its predecessor organization, EPRI's Coal Quality Development Center, for eight years. Harrison came to EPRI from Babcock & Wilcox, where he was in R&D marketing for two years. Still earlier, he was with Pennsylvania Power & Light for seven years. His utility work involved environmental and licensing studies and fuel supply planning.

George Preston, director for fossil power plants in the Generation and Storage Division, has been with EPRI for 12 years. From 1978 to 1984, when he assumed his current position, he worked successively as program manager for desulfurization processes, assistant division director, and director for environmental control systems. Before joining EPRI, he was with Occidental Research for seven years as technical manager for resource recovery programs.

Alex Fremling, deputy director of EPRI's Business Management Group (and also corporate secretary), has been an administrator in the energy field for more than 30 years. He came to the Institute in 1984 as director of administration for the Nuclear Power Division, and from 1986 through 1988 he was director of EPRI's administrative operations. Fremling worked for DOE and its predecessor agencies for over 27 years, including 11 years as manager of the Richland Operations Office, in charge of the Hanford (Washington) federal facility.

George Touchton, as manager of the Fossil Plant Operations Program, guides R&D in computer-based applications for plant controls, automation, monitoring, diagnostics, and expert systems. He joined the Generation and Storage Division as a project manager in 1984 and became a program manager in 1988. Touchton previously was with General Electric for 12 years, primarily in the design, development, and testing of combustion turbines. ■

ELECTRIC POWER RESEARCH INSTITUTE
Post Office Box 10412, Palo Alto, California 94303

NONPROFIT ORGANIZATION
U.S. POSTAGE
PAID
PERMIT NUMBER 99
REDWOOD CITY, CALIFORNIA

ADDRESS CORRECTION REQUESTED

EPRI JOURNAL

April/May 1990