Buying Green Power

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ELECTRIC POWER RESEARCH INSTITUTE

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Cover: Green power—electricity produced by technologies such as photovoltaics, biomass, wind, and hydro—is entering the market for ratepayers who are willing to pay more for environmentally friendly generation options (Art by Celia Johnson)

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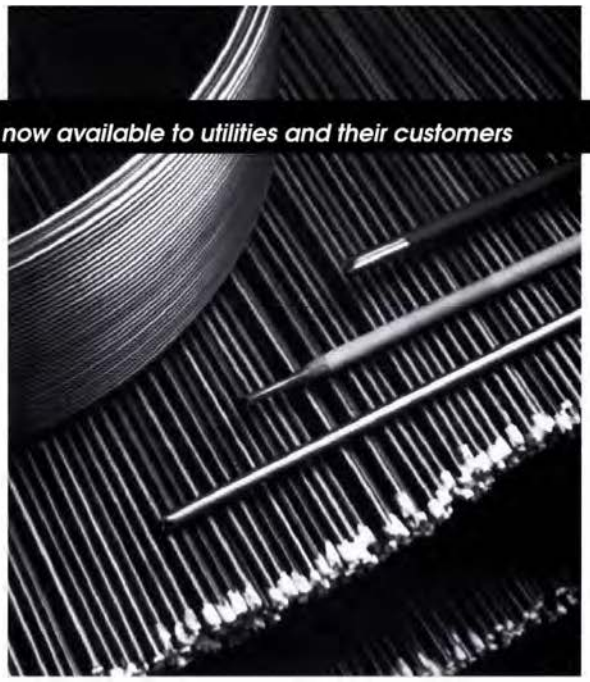

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NOREM is an iron-base hard-facing alloy that resists adhesive wear, cavitation-erosion wear, and corrosion. It was developed by EPRI as an alternative to the standard cobalt-base hard-facing alloys to address issues unique to nuclear applications. This award-winning, patented alloy is available in various forms: powder, rod, and wire. Costs are similar to those of the cobalt-base alloy products. Preheating requirements for welding NOREM are minimal. The alloy is seeing increasing use by utilities in nuclear power plant valves and in hydroelectric plant components. Other organizations are evaluating NOREM for diverse applications.

For more information or to order, call Howard Ocken, (415) 855-2055.

CONSUMER ATTITUDES

In a competitive marketplace, it is critical that electric utilities understand how to hang on to their customers. *ReQuest II: An Investigation of Consumer Attitudes Towards Telecommunication and Electric Services* (TR-106166) illustrates how long-distance and local telephone service providers have attempted to increase customer retention, improve consumption, and build customer loyalty through the marketing of value-added services aimed at specific residential market segments. Based on a survey involving nearly 25,000 consumers—a statistically valid sample that can be projected to any U.S. region—the report provides invaluable insights for developing the best strategies for retaining customers in a competitive marketplace. *ReQuest II* also discusses how appropriate preemptive marketing by an incumbent utility could reduce its vulnerability.

For more information, contact Rich Gilman, (503) 274-4139.

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BLADE

Turbine blade failures have been the leading cause of unplanned utility outages, costing the U.S. utility industry an estimated $200 million annually. To help stem this problem, EPRI developed BLADE—an interactive computer program for managing the life of steam turbine blades. BLADE can help users evaluate turbine blade designs and diagnose problems, can aid in inspection planning, and can provide possible justification for extending outage intervals. Since its introduction in 1991, BLADE has been licensed by over 50 utilities and 7 turbine manufacturers. The new BLADE, version 2.0, allows users to analyze more turbine blade designs and offers a wealth of new capabilities, such as nonlinear friction analysis. Advanced graphic and modeling features include the ability to display the animated motion of blade vibrations.

For more information, contact Tom McCloskey, (415) 855-2655.

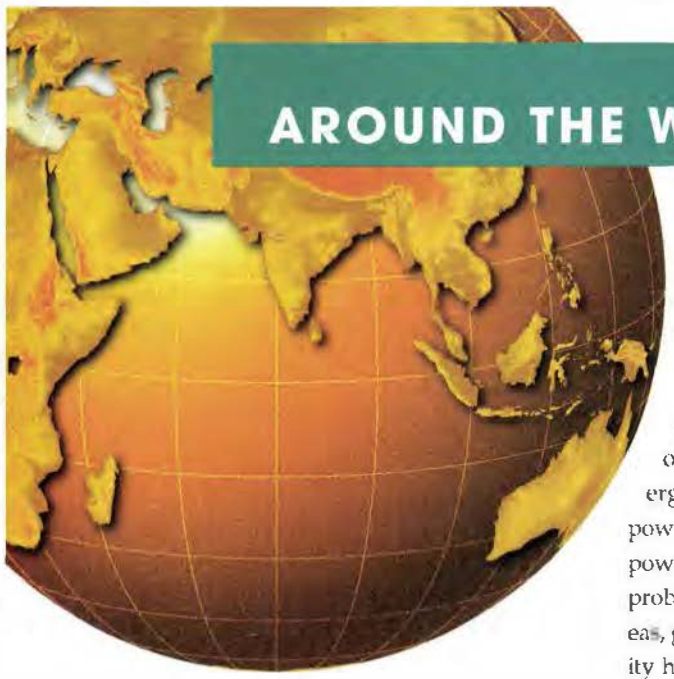
To order, call Stress Technology, Inc., (716) 424-2010.

Lessons From Abroad

As competition in the electric power industry intensifies, the debate about what customers really want to purchase from energy service providers becomes more significant. Will some customers merely want to buy a commodity at the lowest possible cost? Will others be interested in buying a host of customized, value-added services? *Is There Value in Value-Added Service?* (TR-106195) presents some answers from large industrial and commercial customers in the competitive retail markets of England, Wales, and Norway. Their insights have important ramifications for energy service providers in the United States. In a companion report, *The British Privatization Experiment, 5 Years Later: The Winners and the Losers* (TR-106528), British power industry experts provide useful perspective on how well the privatization of the power industry in England and Wales is working so far.
For more information, contact Paul Meagher, (415) 855-2420.
To order, call the EPRI Distribution Center, (510) 934-4212.

ASDMaster

Adjustable-speed drives offer the precise speed and torque control desired in a profusion of applications today, ranging from ocean liners to factory production lines. When considering the installation of an ASD, engineers must closely examine how the drive will interact with other components of an existing system. EPRI created ASDMaster specifically to serve this need. The program ensures a thorough examination of system-wide issues, so users get results they can depend on. ASDMaster will also determine the dollar value of a specific ASD installation, calculate ASD energy consumption and compare it with that of alternative control methods, and generate equipment specifications to submit to ASD manufacturers. This version of ASDMaster is applicable to low-voltage, 1–1000-hp motor installations. A version for medium voltages will be released later this year.
For more information, contact Ben Banerjee, (415) 855-7925.
To order, call the Adjustable-Speed Drive Demonstration Office, (800) 982-9294.



AROUND THE WORLD

Focus on international research and alliances

DVR Installed at Australian Dairy Plant

A Dynamic Voltage Restorer, a power electronics control device developed by EPRI and Westinghouse to provide premium-quality power for industrial customers, has been installed in Stanhope in Victoria, Australia—the first DVR to operate on a 50-Hz power system. The new DVR was dedicated in February by Powercor Australia Limited to serve the Bonlac Foods dairy processing plant. Last year, the world's first DVR—a 60-Hz device—was installed by Duke Power at Orian Rugs in Anderson, South Carolina. Both projects will demonstrate the value of the DVR technology to manufacturers with sensitive production processes.

The DVR, developed at the Westinghouse Science & Technology Center in Pittsburgh, is the latest and most advanced of several electronic power controllers that are part of the EPRI and Westinghouse Custom Power product family. "Many industrial processes use computerized control. Momentary power disturbances that once might have gone unnoticed—disturbances such as voltage sags, swells, transients, or harmonics—can now cause production to stop," says EPRI's Karl Stahlkopf, vice president for power delivery. "Custom Power devices like the DVR are offering utilities better ways to control distribution power quality for their customers."

The DVR protects sensitive end-use equipment from voltage fluctuations on a power line by rapidly injecting energy onto the line to compensate for the power disturbance. In Australia, changes in power supply voltages can be a particular problem for processing plants in rural areas, given the distances over which electricity has to travel and the effects of weather, dust, and other factors on the lines. "We are aware that large manufacturing plants such as Bonlac Foods can be affected by even slight variations in power supply," says Dan Spalding, chairman and CEO of Powercor Australia, the area's electricity supplier. "This new technology will help to minimize power supply disruption."

In addition to Bonlac Foods and Powercor, the dairy plant's DVR installation is supported by Eastern Energy, Westinghouse, EPRI, PowerNet, Business Victoria Department of State Development, and Murray Development (via funding from the Australian federal government). Bonlac will monitor the performance of the DVR for one year, and Powercor plans to share the DVR test results with other firms and industries.

The Powercor DVR has a rating of 2 MVA with 660 kJ of energy storage. In the event of a three-phase 50% voltage sag during Bonlac's off-peak production periods, the DVR is capable of restoring voltage to 95% for one-third of a second. In the event of a 35% three-phase sag (i.e., 65% retained voltage) during peak production, it is capable of restoring voltage to 99% for one-third of a second. Westinghouse is now accepting commercial orders for DVR systems with ratings from 2 to 10 MVA (in 2-MVA increments).

■ *For more information, contact Ashok Sundaram, (415) 855-2304.*

Hydraulically Driven Pump Tested in St. Petersburg, Russia

Boiler circulation pumps play a critical role in power plants with high-temperature and high-pressure conditions, and their importance is growing with the increased use of high-efficiency, once-through boilers in cycling applications. Difficulties inherent in the design of electrically driven boiler circulation pumps have resulted in reduced availability and high maintenance costs in U.S. power plants. Current-generation pumps of this kind are large and complex, and servicing them adds substantially to maintenance costs and plant downtime. Recent EPRI work found that a hydraulic-turbine-driven boiler circulation pump developed in Russia over the past several years may offer an attractive alternative to electrically driven pumps.

An EPRI project team participated in field tests of a hydraulic circulation pump at the 250-MW supercritical unit of Lenenergo's Southern power plant in St. Petersburg, Russia. In addition to observing normal operation, researchers performed a

special series of tests on the boiler to determine the effectiveness of the pump during startup modes.

The hydraulic circulation pump is a centrifugal pump contained in a hermetically sealed unit. The bearings are hydrostatic, and the driving fluid is boiler feedwater. Unlike the motor in an electrically driven pump, the hydraulic pump's components are designed to handle the boiler water temperature and pressure. The pump is much more compact than electrically driven units and can be easily opened for maintenance. Variable-speed operation is possible with the use of throttling valves.

The Russian hydraulic pump has performed reliably and efficiently in large supercritical power plants for many years. The circulation pumps at the Lenenergo Southern plant have been in operation for six years without any failure or repair. In

COURTESY JOINT STOCK COMPANY LENENERGO

terms of power consumption, they were found to be equivalent or somewhat superior to traditional hermetic pumps with electric drives. Moreover, the test results in the startup mode showed that the hydraulic pumps have significant advantages for cycling operation.

The EPRI project recommended a three-phase program to further investigate operating experience with hydraulic pumps and, eventually, to field-test such pumps built to U.S. standards. An EPRI report (TR-105532) on the St. Petersburg field tests is available from the EPRI Distribution Center.

■ *For more information, contact Walter Piulle, (415) 855-2470.*

Monitoring and Diagnostic Technology Transfer With Electricité de France

With 29 million customers and about 99 GW of installed generating capacity, Electricité de France is, by those measures, the world's largest electric utility. For the past three years, EdF has been a funding member of EPRI's Monitoring & Diagnostic Center—located at PECO Energy's Eddystone plant near Philadelphia—where EPRI advanced technologies and expertise are being brought to bear on improving the performance and availability of power plants in France.

Renowned for its fleet of nuclear power plants, which account for over 80% of its total electricity generation, EdF also has 17,400 MW of installed fossil generating capacity—half coal-fired, half oil-fired. But today the fossil plants produce only about 4% of total generation, and approximately half of the fossil capacity is shut down. EdF intends to increase fossil power generation in the future to compensate for the retirement of some nuclear capacity, and this will significantly raise fossil plant capacity factors.

Since 1994, EdF personnel have visited the M&D Center for technology transfer training courses, including advanced vibration analysis, generator diagnostics, and acoustic leak detection. M&D Center personnel have also visited EdF facilities and have participated in an EPRI international symposium on diagnostic techniques and methods.

EdF is particularly interested in the areas of expert systems, fossil plant monitoring systems, and infrared thermography. In working sessions, EdF and center staff

have shared developments in expert system software, and recently M&D Center specialists made two visits to EdF to demonstrate methods and procedures for conducting infrared thermography surveys.

The results of EdF's transfer of EPRI technology will be seen at several French fossil power plants, including the largest and newest—the five-unit, 3110-MW coal-fired Cordemais plant on the Brittany coast.

The French utility has agreed to continue this year as an M&D Center member and is considering expanding its association with EPRI in other R&D target areas. "The feedback we've gotten from EdF personnel so far has been very positive. They've indicated that they have learned a lot and have received substantial value from their membership investment," says Bob Matusheski, a project engineer at the M&D Center.

■ *For more information, contact Michele Blanco, (415) 855-8705.*

Utility Customers Go for the Green

by Leslie Lamarre

THE STORY IN BRIEF

In a world where most folks want to see their power bills go down, a growing contingent of electric utility customers actually looks forward to seeing them go up. These consumers and businesses are involved in a relatively new phenomenon called green pricing. Now offered by more than a dozen electric utilities in the United States, green pricing programs give customers the option of paying more for their electricity to help fund the installation of environmentally friendly power generation.

As a result of these efforts, photovoltaic panels have been installed on school roofs, new wind turbines are being erected in windy passes, and biomass and hydropower plants are running closer to capacity. In this era of increasing competition, more electric utilities are turning to green pricing as a way to satisfy a well-defined—and expanding—customer niche.

Bob Petersen's electric bill has more than doubled, and he couldn't be more pleased. That's because he's supporting the development of solar power. For an extra $50 a month, Petersen and his wife, Kathy, have the satisfaction of knowing that they've funded the production of some 105 kWh—about 20% of the electricity they use—from a new photovoltaic plant established by their electric utility, Detroit Edison.

The Petersens are part of a growing contingent of U.S. consumers who are digging into their own pockets to help foot the bill for green power. Through a phenomenon called green pricing, these consumers agree to pay their electric utilities more for power generated by environmentally friendly technologies. For the most part, they don't even get to use the electricity directly. But for folks like the Petersens, the gratification of bringing something good onto the grid is enough. "I'm happy to be part of something that will improve our quality of life in the future," says Petersen, an environmental engineer in Livonia, Michigan, a suburb of Detroit. "I've always been interested in environmental issues. I'm also interested in the future—what my kids will have and beyond. Environmental quality is important."

Whether green pricing comes in the form of a flat monthly fee, a per-kilowatthour charge, or a simple rounding up to an even dollar on a utility bill, it is cropping up all over the country, from Michigan to Colorado to Hawaii. As of January, at least 13 utilities have green pricing programs in place, dishing up photovoltaic panels, wind turbines, and even biomass generation. According to Ed Holt, editor of the *Green Pricing Newsletter* and a close observer of green pricing activity nationwide, another 5 utilities are planning to offer green rates this year and 15 more

GREEN PRICING—NATIONWIDE As of early this year, more than a dozen electric utilities in the United States offer their customers a green choice when it comes to the type of power they'd like to buy. Abundant solar resources, the modular nature of photovoltaic panels, and widespread public enthusiasm for PV technology make it by far the most common generation technology involved in green pricing programs.

Sponsor and Program	Year Launched	Renewable Type	Renewable Capacity	Market Segment	Number of Participants	Funding Mechanism	Monthly Customer Cost
City of Austin Electric Utility: Solar Explorer	1997	PV	219 kW	Residential and business	NA	Fixed payment	$7
Detroit Edison: SolarCurrents	1995	PV	28.4 kW	Residential	195 residential*	Fee per 100 W (minus electricity credit)	$9.89 (avg.)
Florida Energy Extension Service and Gulf Power: Solar for Schools	1996	Solar thermal and PV	100 W PV (for lights)	Residential	513	Fixed payment	$1.75
Fort Collins (Colorado) Light & Power: Wind Power Pilot Program	1996	Wind	750 kW per turbine	Residential and business	NA	Fee per kWh (residential); fee per 1000-kWh block (business)	$10 residential (est.)
Gainesville Regional Solar Project	1993	PV	10 kW	Residential and business	657	Contribution	$3.27 (avg.)
Hawaiian Electric Co. and subsidiaries: Sun Power for Schools	1996	PV	8–16 kW (min.)	Residential and business	NA	Contribution	NA
Northern States Power: EnergyWise Solar Advantage for Homes	1995	PV	34 kW	Residential	17*	Fixed payment (minus electricity credit)	$36 (est.)
Portland General Electric: Renewable Energy Supply	1996	Wind	NA	Large commercial and industrial	NA	Fee per kWh	NA
Public Service of Colorado: Renewable Energy Trust	1993	PV	13 kW	Residential	14,000	Contribution	$1.77 (avg.)
Sacramento Municipal Utility District: PV Pioneers	1993	PV	1200 kW	Residential	350*	Fixed payment	$4
Traverse City (Michigan) Light & Power: Green Rate	1994–1995	Wind	600 kW	Residential and business	145 residential 20 business*	Fee per kWh	$7.58 residential (avg.) $27 business (avg.)
Wisconsin Electric Power: Energy for Tomorrow	1996	Hydro and biomass	5 MW	Residential and business	NA	Fee per kWh	$3, $6, or $12, depending on option chosen
Wisconsin Public Service: SolarWise for Schools	1995	PV	36 kW	Residential	2600	Contribution	$1.64 (avg.)

Source: Ed Holt & Associates, Harpswell, Maine.
*Participation limited by project size.

PREVIOUS PAGES: WIND TURBINES BY BARRIE ROKEACH/IMAGE BANK; PV PANELS COURTESY NORTHERN STATES POWER; SUGARCANE BY GARY CRALLE/IMAGE BANK

are considering the possibility. Each of the existing programs has surfaced within the past four years.

Why all of this activity in green pricing now? To start with, consumers want it. While environmentalism isn't exactly booming these days, it certainly has steady support. The proliferation of curbside recycling programs, environmentally motivated companies, and environmentally friendly products—ranging from laundry detergent with less packaging to mutual funds focused on green investments—is an indication of this significant public interest. In fact, environmental issues appear to have burst from the domain of career conservationists and into the mainstream of public consciousness, as problems like poor air quality become visible in our day-to-day lives.

Consumer enthusiasm for renewable energy generation technologies is part of this trend. According to Barbara Farhar of the National Renewable Energy Laboratory, data from national polls over the past 18 years indicate that the public has a "strong and consistent preference for energy efficiency and renewable energy." This is one conclusion Farhar draws in the report *Energy and the Environment: The Public View*, released last November. Farhar's report synthesizes data from more than 700 polls between 1973 and 1996. It notes that between 56% and 80% of respondents to recent national surveys said they would pay a premium for environmental protection or renewable electricity. And that's a good thing: although renewables have declined in price significantly over the past decade, most are still not quite competitive with their fossil fuel alternatives.

The strong consumer interest in green power also coincides with the early stages of deregulation in the electric utility industry—a time when utilities are paying closer attention to what their customers want. "Utilities are understanding that whereas before they mass-marketed everything, now they have to start appealing to niches in their customer base," says Maribeth Rahimzadeh, a market planning consultant with Wisconsin Public Service Corporation and a former green pricing advisor to the utility. Rahimzadeh sees green pricing as a great first niche in which utilities can try their hand at marketing. "Green pricing is really the first horse out of the stable," she says. "It's a test—a really good way for a utility to see whether it has all the marketing tools it needs in order to roll out a competitive product or service."

Because successful green pricing programs can help build customer satisfaction and loyalty while projecting a positive company image, some utilities are jumping at the opportunity to cater to this well-defined market niche. And customers are eating it up. Detroit Edison's SolarCurrents program, through which residential customers purchase small portions of photovoltaic generating capacity, is so popular that it quickly became oversubscribed, leaving about 70 customers on a waiting list. Through this program, participants agree to subscribe for 100-W increments of PV service, committing to a two-year contract of fixed monthly fees and a solar energy delivery charge. Each month their bills are credited with a proportionate quantity of solar-generated kilowatthours, which will vary depending on how much electricity the plant produces. The power goes directly onto the utility grid.

Some 145 residential and 20 business customers of Traverse City Light & Power increased their electricity rates to pay for this 600-kW wind turbine near Lake Michigan.

Wisconsin Electric customers voluntarily increased their monthly bills to put idle capacity of this biomass plant to use. The plant is fueled by waste wood from forest-product industries—scrap that would otherwise be trucked to a landfill.

ANDY BLACK/ONGRID SOLAR ENERGY SYSTEMS

Volunteers install a 1.5-kW PV system at the Carbondale, Colorado, middle school. The project was funded by customer payments to Public Service of Colorado's Renewable Energy Trust.

The 195 SolarCurrents subscribers pay an extra $6.59 per month for every unit of PV service they purchase. On average, their voluntary contributions increase their electric bills by 14%. Petersen is among the largest solar contributors, subscribing to six units, which brings his electric bill up to about $87 a month, from about $37. "I felt that we could afford it without major cuts in the way we live," he explains.

Motivated

Combined, customers' SolarCurrents subscriptions cover about 48% of the $225,000 cost of a 28.4-kW array near Ann Arbor, Michigan, which delivered its first electricity on May 1 of last year. A grant from the U.S. Department of Energy covers the remaining cost of the equipment, with Detroit Edison picking up the promotional and other administrative expenses. Detroit Edison plans to continue installing PV as long as customers want to contribute and is hoping to bring another 160 kW of solar power on-line this year. (Studies by the utility show that property it already owns could support up to 200 MW of PV.)

"Working together with our customers, we will be able to bring down prices for this technology, just as we've seen prices of calculators and computers come down in the past several years," says Norm Stevens, program manager for SolarCurrents. "When competition is in full swing, it's an option we'll have for our customers interested in solar." Stevens says that part of the utility's motivation for establishing SolarCurrents was market research showing that some 30% of residential customers surveyed were willing to pay more for their electricity to speed the introduction of renewable energy technologies.

Customer interest was a similar motivator for Public Service of Colorado, whose service territory includes such environmental enclaves as Boulder. Nestled in a 30,000-acre greenbelt of open space at the foot of the Flatiron Mountains—a haven for rock climbers—this university town is well known for its love of the outdoors. Recycling is a way of life for 75% of its residents, who frequent businesses with names like Eco-Cycle and Sundance Adventures. So it's not surprising that people here responded well to a green pricing offer from PSC.

Launched in 1993, PSC's Renewable Energy Trust was one of the first green pricing programs established in the country. Customers throughout PSC's service territory can contribute to the trust simply by opting to round up their utility bills to the nearest dollar, although some prefer to donate a flat monthly fee. With 14,000 contributors, the program is the country's largest in terms of participants. Together, they contribute about $150,000 annually. The tax-deductible contributions are used to purchase and install PV panels for nonprofit facilities—such as remote firehouses, campgrounds, and museums—that are largely off-grid. (PSC subsidizes the project at about $1 per watt.) Over the past three years, the trust has funded the installation of 13 kW of PV. "It amounts to a few pennies added onto your bill, which makes it very easy to do and feel good about yourself," says Denise Coté of Boulder, a contributor and a member of the trust's advisory board.

In February, PSC received preliminary approval from its public utility commission to launch a second green pricing program, called Windsource. Through this ambitious program—expected to be the country's largest in terms of renewable generation capacity—customers will be able to buy 100-kWh blocks of wind power. PSC has committed to constructing 10 MW of Colorado-based wind power, assuming the anticipated customer demand exists. "Our customers are asking us to provide them with alternatives to fossil fuels," says Steve Dayney, who heads up PSC's green pricing efforts. "It is incumbent on us to provide what they want." Dayney is confident that customer contributions will fully support the program, since the region's

GREEN IS GOOD FOR BUSINESS TOO **Although many green pricing programs have focused on the residential market segment, a number of utilities are finding that businesses are interested too. In Fort Collins, Colorado, 10 businesses have demonstrated their commitment to the environment by signing up to make higher monthly payments to their local utility, Fort Collins Light & Power. The money will help pay for a new wind turbine.**

Bike Broker

Roberto's Burritos

Kramer and Houston Towing

PHOTOS BY DON MCFANN/FORT COLLINS LIGHT & POWER

good wind resources make wind power economically competitive with traditional generation sources. The city of Boulder and local environmental groups will assist PSC with the promotion and marketing of Windsource, which is expected to be launched this spring.

PSC plans to establish a third green pricing program later this year that will involve the installation of PV panels on the roofs of grid-connected residential customers. These homes will use the solar power directly; their meters will spin backward when any excess electricity from the panels flows onto the grid and forward when electricity is drawn from the grid. Called net metering, the measurement of electricity in both directions enables a utility to track the net electricity used by a given customer.

Business interest

Although green pricing programs have traditionally been geared toward the residential market segment, some utilities are finding that commercial customers—including restaurants, sporting goods stores, and even towing shops—are interested too. After all, being able to call your company green can go a long way with some consumers. According to Environmental Futures, Inc., a Boston-based consulting firm that specializes in helping companies become more environmentally responsible, recent national surveys show that 83% of consumers say a company's environmental reputation influences their choice of brands, 66% would switch brands if a comparable brand were better for the environment, and 62% have not bought a particular brand or product because of environmental concerns.

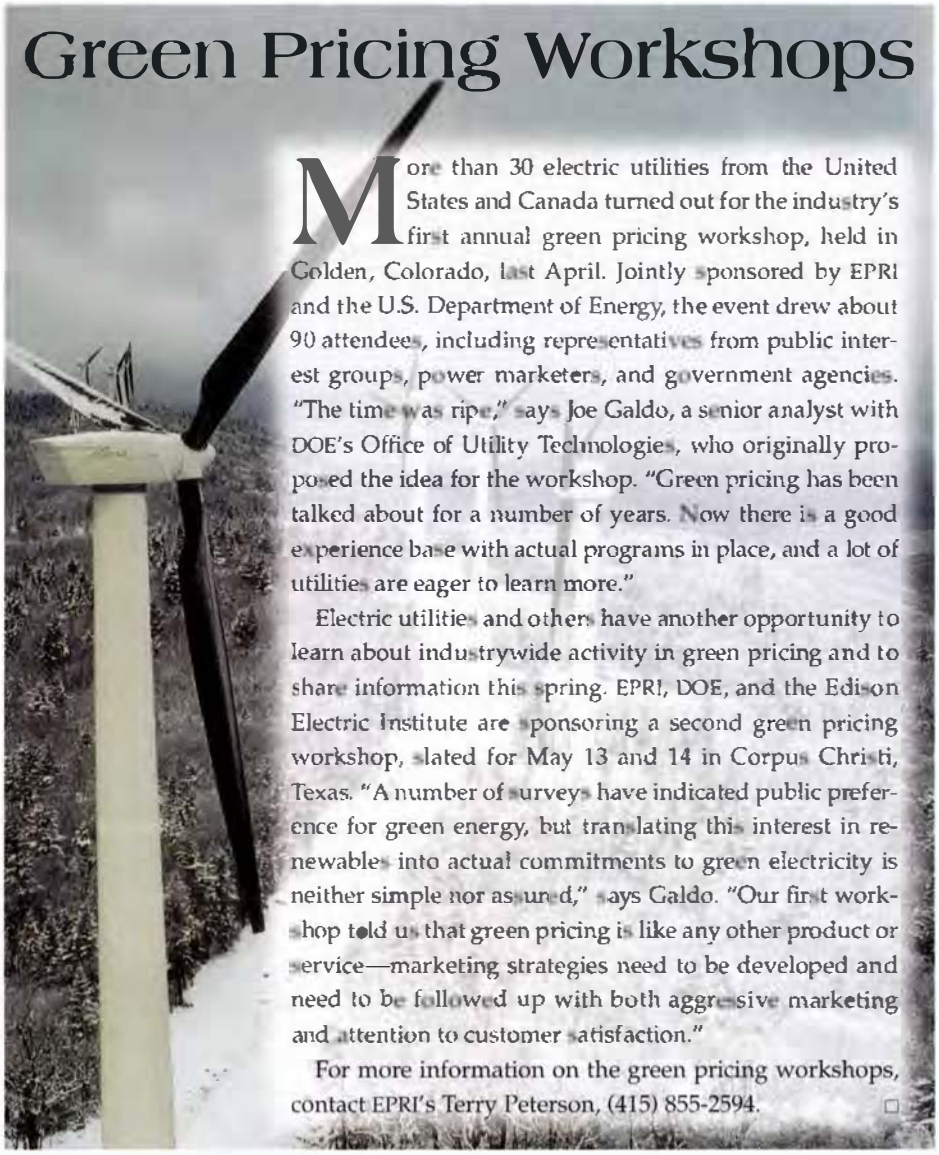
Powering up a business with ecowatts (as some like to call environmentally friendly kilowatts) adds a new dimension of greenness to a company that already recycles its paper and prints with soy-based inks. And it's an option some businesses are finding hard to resist. "Many of our customers are very in tune with the environment," says Randy Morgan, the owner of Outpost Sunsport in Fort Collins, Colorado, one of 10 commercial customers that signed up for a wind power program offered by Fort Collins Light & Power Department. (Others include Roberto's Burritos, the Bike Broker, Kramer and Houston Towing Company, and Walrus Ice Cream.) Fort Collins is located just north of Boulder in Colorado's Front Range region, an area that's become almost as well known for its lingering brown cloud—air pollution generated by the region's burgeoning population and trapped by its topography—as for its beauty. "From a distance, you can see a brown cloud—haze all the way from Colorado Springs to Fort Collins," Morgan says. That's a 140-mile stretch. To witness the pollution daily "makes you more acutely aware of the problem," he says.

Fort Collins's program, its first experience with renewable energy, will result in the installation of at least one 750-kW wind turbine, which can power 350 homes. So far, some 650 residential customers have signed up. "Since we're so close to 700, we would really like to build a second turbine," says Steve VanderMeer, director of marketing and energy services for the municipal utility. The wind power will be installed within 100 miles of Fort Collins at a site still to be determined. The money from residential and commercial participants is expected to fully cover the cost of the turbines. For his part, Morgan estimates his business will pay an extra $40 a month, or 5% more, for its electricity. That doesn't include the $15 he's spending to participate at home. Morgan recognizes that this one small electricity generation project is not going to resolve the air quality problems of the Front Range region. Still, he views it as a worthwhile investment. "I'm very supportive of nonpolluting power sources and would like to see that they be further developed," he says.

Utilities have found that commercial enthusiasm for green rates depends on how the financing of a given program is structured. For instance, programs involving specific charges per kilowatthour have not proved to be hugely successful with large energy users, whose electric bills could skyrocket under such a plan. For this reason,

Outpost Sunsport

Walrus Ice Cream



COURTESY GREEN MOUNTAIN POWER CORP.

Green Pricing Workshops

More than 30 electric utilities from the United States and Canada turned out for the industry's first annual green pricing workshop, held in Golden, Colorado, last April. Jointly sponsored by EPRI and the U.S. Department of Energy, the event drew about 90 attendees, including representatives from public interest groups, power marketers, and government agencies. "The time was ripe," says Joe Galdo, a senior analyst with DOE's Office of Utility Technologies, who originally proposed the idea for the workshop. "Green pricing has been talked about for a number of years. Now there is a good experience base with actual programs in place, and a lot of utilities are eager to learn more."

Electric utilities and others have another opportunity to learn about industrywide activity in green pricing and to share information this spring. EPRI, DOE, and the Edison Electric Institute are sponsoring a second green pricing workshop, slated for May 13 and 14 in Corpus Christi, Texas. "A number of surveys have indicated public preference for green energy, but translating this interest in renewables into actual commitments to green electricity is neither simple nor assured," says Galdo. "Our first workshop told us that green pricing is like any other product or service—marketing strategies need to be developed and need to be followed up with both aggressive marketing and attention to customer satisfaction."

For more information on the green pricing workshops, contact EPRI's Terry Peterson, (415) 855-2594. □

power companies typically develop a different formula for commercial customers. In the Fort Collins program, residents pay an extra 2¢ for every kilowatthour of electricity they use, but commercial customers buy their green power in monthly blocks of 1000 kWh, which cost an additional $20 each. The block option allows these bigger energy users to determine their level of participation.

In terms of the actual dollars utility customers are willing to contribute, research has shown that small commercial customers typically far surpass residential customers. For instance, surveys by Wisconsin Public Service found that an equal percentage of its commercial and residential customers were willing to pay premiums to fund the installation of PV systems on high-school roofs. But the costs acceptable to commercial customers were 1000–5000% more than those acceptable to residential customers. Says Rahimzadeh of WPS, "Our commercial customers are interested for much the same reasons we are: green power provides a link to their customers and the communities they serve." Besides, she says, "they get a lot of mileage out of it, as they should."

WPS's SolarWise for Schools program, established in 1995, allows customers to make tax-deductible contributions to a trust that is used to purchase, install, operate, and maintain PV systems on high-school rooftops. The power goes directly to the school buildings. The utility also provides curriculum materials about solar energy and trains teachers to instruct students on the topic. The program has proved fairly successful, drawing a total of 2600 residential customers, who contribute an average of $1.64 monthly. As a result, 12-kW PV systems have been installed on the rooftops of three local high schools. WPS is now considering expanding the program to the commercial market segment. The SolarWise for Schools program influenced a similar program that Hawaiian Electric Company and its subsidiaries launched for their residential and commercial customers this year.

According to Richard Weijo of Portland General Electric, there are some advantages in pursuing bigger customers. "With the residential market, there are significant educational and training requirements to explain what you're doing," says Weijo, who oversaw a trial residential PGE program called Share the Wind, which offered bill rounding up and even marketed credit cards and debit cards to support wind power. "With commercial and industrial customers, the marketing costs are minimal because we already have a direct sales force that works with these customers." PGE recently introduced a pilot wind-based green pricing program to commercial and industrial customers.

Disclosure

Some experts predict that green rates will become more commonplace in the early stages of deregulation. That's because utility commissions are beginning to require that utilities disclose their generation sources. "If consumers knew more about what goes into making their kilowatthours, they'd be more focused on the environmental aspects of generation, just as they've become more aware of their food because of nutrition labeling," says Steven M. Rothstein, president of Environmental Futures. Indeed, more-detailed nutrition information on food packaging has contributed to an increased health consciousness in the United States, where people now track fat grams, cholesterol, and sodium content as dutifully as they do checking-account balances.

The practice of disclosing generation sources was endorsed by the National Association of Regulatory Utility Commissioners at its annual convention last November. NARUC's resolution urges states to include

disclosure requirements for price, price variability, and generation technologies in their deregulation plans. Since the passage of NARUC's resolution, at least three states —Massachusetts, Maine, and Vermont— have proposed restructuring plans that include disclosure requirements. And a draft of the Clinton administration's restructuring bill, released in November, includes a requirement for disclosure. "It's catching on," says Ed Holt. "I think a number of regulators are beginning to understand the importance of providing good information to consumers so that they can make the choices they'll have to make when retail access becomes available."

Some in the industry would like to go even further than disclosure, suggesting that green power be certified by an independent organization that would offer a seal of approval on a power company's claim of being green. Such certification practices are now being implemented for other types of green products, such as energy-efficient office equipment, which is certified through the EPA's Energy Star program. Paints, cleaners, and other household products are similarly certified by the Washington, D.C.–based Green Seal organization. Even lumber is being certified to ensure buyers it was harvested in a sustainable manner that respects wildlife habitat and biodiversity. In Europe, certification is being carried out by environmental groups like the World Wildlife Fund, Holt says. While many industry and public interest groups in the United States are actively discussing the certification issue, no formal certification process has yet been established here.

Clearly, the task of defining greenness involves a value judgment. "There is no absolute answer to the question of what is green," says Terry Peterson, EPRI's manager for solar power and green pricing. "It really depends on which environmental issues concern you most." For instance, if a consumer is concerned about air pollution and acid rain or smog, then nuclear power might seem like a good trade-off. But another consumer might be more troubled by nuclear waste. Hydropower in any form is viewed as green by some, although large projects that involve flooding wildlife habitats and the lands of indigenous people have drawn much criticism from environmentalists. Emissions-free fuel cells may not be a truly renewable form of energy generation if they are fueled by natural gas, but they certainly provide a clean alternative to fossil-fired generation.

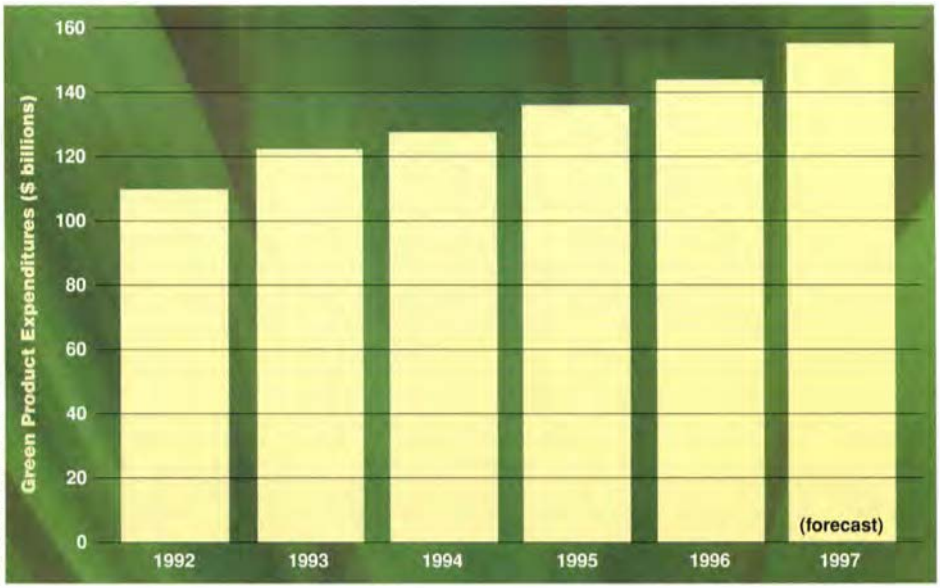
THE POWER OF DISCLOSURE **Some power industry observers believe that in a competitive market electric utilities should be required to disclose their generation sources, much as food manufacturers are required to disclose nutrition information on their packaging. Experts say disclosure would attract increased consumer support for environmentally friendly power generation.**

TED KAWALERSKI/IMAGE BANK

"No generation technology is without issues," says Peterson, noting that even the most seemingly benign renewable resources have drawn flak. For instance, some critics view PV panels as a blight on the landscape and wind turbines as a potential death trap for certain bird species. "Anytime you generate power, there is the potential for negative environmental impact," says Peterson. "It's a question of degree."

A renewable future

While electric utilities have experienced favorable responses to their green pricing efforts, they have also fielded some criticism. Some skeptics ask why consumers should pay a money-making company for something it should be doing on its own. Green pricing advocates counter that many of the utilities are already investing in renewables projects but that green pricing programs allow them to do more while providing a means for environmentally conscious customers to support something they believe in.



SOURCE: GREEN MARKET ALERT

GREEN PRODUCTS ARE RED-HOT **The market niche for green products has experienced considerable support over the past five years. The steady rise in consumer expenditures on green products is expected to continue this year—for a 40% increase since 1992.**

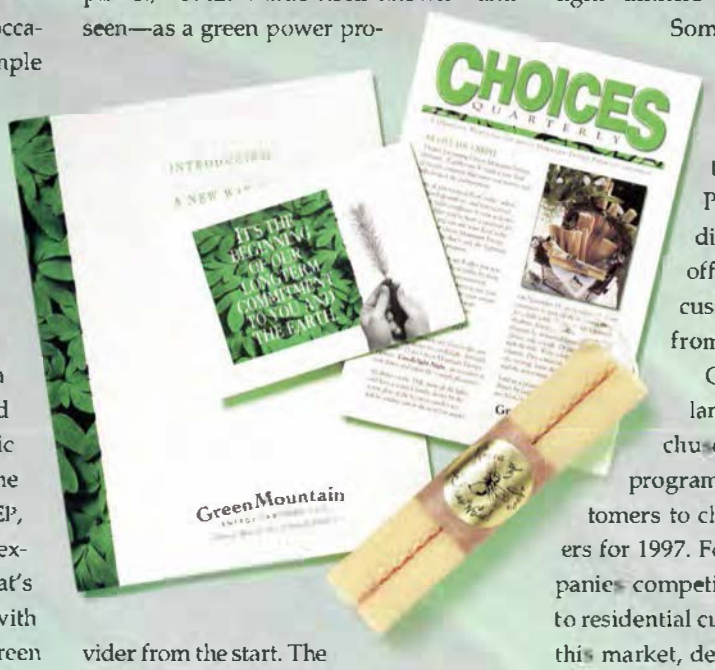
Green Marketing

The cardboard box delivered to each of Green Mountain Energy Partners' new customers certainly seemed like a curious package: too bulky for an electric bill, too long and thin for a lightbulb. Inside was a pair of beeswax candles and a note from the new power supplier. Use these for a candlelight dinner on November 15, "an occasion to slow down and enjoy life's simple pleasures," it said.

The candles are just one element of what has turned out to be a very successful—and very green—marketing campaign for GMEP. The company was among 35 power suppliers competing to provide electricity to 16,800 New Hampshire customers for up to two years as part of a pilot program to test the concept and practice of competition in the electric utility industry. At least four of the competing companies, including GMEP, billed themselves as green. Industry experts say this is just a glimpse of what's to come in full-fledged competition, with green marketing (as opposed to green pricing) playing a stronger role. "A little bit of competition certainly helps bring out the green," says Terry Peterson, who oversees EPRI's green pricing research. "A green image is one way to set your company apart. And it sells."

Whereas green pricing programs ask customers to pay more to add environmentally friendly generation to a utility's resource mix, green marketing simply capitalizes on the already green aspects of a power company's personality. Often no rate increase is involved. In fact, GMEP's rates save the average residential customer in New Hampshire about 15%.

Kicking off its campaign with the catchy slogan "Choose wisely. It's a small planet," GMEP made itself known—and seen—as a green power provider from the start. The company boasted that 90% of its electricity supply is from hydropower sources, and it plastered its name and slogan on a hot-air balloon, which it set aloft during various marketing events across the state. It also established the EcoCredits program, through which customers can earn deductions on their power bills for environmental gestures, much as people earn mileage awards on various airlines.



WEINBERG & CLARK

GMEP says it won about 15% of the residential market, the highest share achieved by any new entrant into the New Hampshire market. The beeswax candles arrived on the doorsteps of these new customers last fall. Those who responded with pictures of their candlelight dinners earned two EcoCredits. Some even attached notes about the event. "We couldn't have written some of these letters better ourselves," says Andy Perkins, GMEP's assistant director of marketing, whose office wall is papered with customers' notes and pictures from Candlelight Night.

Green marketing was similarly successful in Massachusetts, where another pilot program allowed about 5300 customers to choose their power suppliers for 1997. Four of the six power companies competing offered green options to residential customers, snagging 31% of this market, despite rates that were generally higher than the rates of the so-called price options. (The rates for all the green options were still lower than the 3.5¢ per kilowatthour that residents paid for generation before the program.)

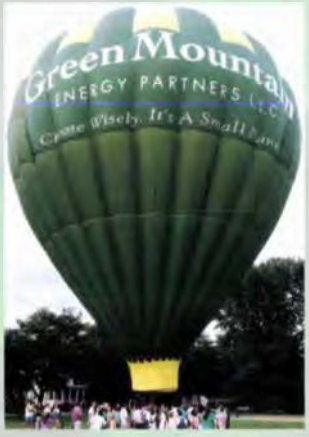
While billed as green, not all the green options meet everyone's criteria for environmentally benign generation. The most successful green competitor, the San Francisco company Working Assets—

Other critics complain about free riders, pointing out that a few motivated and concerned citizens are supporting a cause that benefits everyone in terms of cleaner air. "To place the burden on one group of consumers means that, unfairly, a few volunteers are paying for the societal benefits of renewables," says Randy Swisher, director of the American Wind Energy Association. Swisher supports the concept of green pricing but insists that other measures must be taken too. "Voluntary efforts cannot replace public policy," he says. AWEA developed the Renewables Portfolio Standard, which would require, as a condition of doing business in a given state, that every power supplier selling electricity directly to customers purchase a percentage of its energy from renewable resources. Some states are incorporating this standard into their restructuring plans. Others are adopting alternative types of mechanisms to support green power. For instance, California recently passed a bill with a provision that allows residential customers who buy at least half their power from renewable resources to choose their electricity suppliers starting January 1 of next year—as much as five years before other residents of the state.

Contributing to the concern about free riders is the fact that most green pricing programs fund generating capacity that

which had already garnered a green niche in the telephone and credit card service industries and which captured 16% of the residential market in the Massachusetts pilot—defines its standard of green by what it is not: no coal, nuclear, or large-scale hydropower is included in its generation portfolio. The company also donates 1% of its revenues to Massachusetts environmental groups. Another green competitor, Northfield Mountain Energy of West Springfield, Massachusetts, describes its generation as 100% hydropower, offers customers free energy conservation products and a home energy survey, and makes donations to local green projects. AllEnergy of Waltham, Massachusetts, has only 6% renewables in a generation mix that includes coal, gas, nuclear, hydropower, and oil, but it agrees to eliminate a certain level of sulfur dioxide emissions annually for every customer. San Diego's Enova Energy has only 2.29% renewables in a generation mix that includes nuclear, coal, oil, and hydropower, but it offers its customers energy surveys, "earth saver" kits, matching donations for environmental projects, and a raffle for an electric vehicle.

Whereas green pricing programs ask customers to pay more to add environmentally friendly generation to a utility's resource mix, green marketing simply capitalizes on the already green aspects of a utility's personality. Often no rate increase is involved.



COURTESY GREEN MOUNTAIN ENERGY PARTNERS

"We tried to get the greenest things that were available for a pilot program," says Steven M. Rothstein, president of Environmental Futures, the program's administrator. "It's important not just to look at the source of supply." □

feeds power onto the utility grid, where green electrons mingle with electrons from coal, nuclear, oil, and other types of power plants. "The technology simply doesn't exist to deliver the appropriate amount of green electrons to the doorstep of each contributing customer for their exclusive use," says Holt. But this does not bother many green pricing program participants. "The financial transaction is the important point," Holt explains. "The money somebody pays actually results in a particular plant or type of plant being dispatched." And putting green power plants to work reduces emissions from other power plants.

A few programs, such as the one that PSC plans to launch later this year, actually do offer customers direct use of green power. A similar program is already in place at Northern States Power. Called the NSP EnergyWise Solar Advantage for Homes program, it involves the installation of PV panels on the roofs of customers' homes. The resulting electricity is used directly by each participating household. As is the case with PSC's planned program, the utility meters power in both directions so that customers can either sell excess power back to the grid or buy more power from the grid as needed.

In the meantime, there are significant indications that the green power market is beginning to fend for itself. On January 6, Enron Corporation, one of the world's largest natural gas companies, announced that it had acquired Zond Corporation of Tehachapi, California, a leading wind energy developer, operator, and manufacturer. At the same time, the company formed a new business unit, Enron Renewable Energy Corporation. "Renewable energy will capture a significant share of the world energy market over the next 20 years, and Enron intends to be a world leader in this very important market," says Kenneth Lay, chairman and CEO of Enron. This move is the company's second major investment in renewable energy technology; in January 1995, it entered a joint venture with Amoco, called Amoco/Enron Solar, to manufacture PV modules for grid-connected applications and to develop solar-powered electric generating facilities around the world. Today, Amoco/Enron Solar is the largest U.S.-owned producer of PV cells and the second largest in the world.

Many industry observers maintain that green pricing will survive as long as it is needed—that is, until the costs of the renewable energy technologies most valued by society decline to the extent that they are truly competitive with fossil-fired generating capacity. While the fate of green power in a competitive market remains to be seen, one thing's for sure: green pricing is helping to apply renewable energy technologies and to educate the public about renewable energy. And few can argue with that. In the words of Bob Petersen of Livonia, Michigan, "Somebody's got to do it. I'm just hoping that there are enough somebodies like me." ■

Background information for this article was provided by Terry Petersen and Jim Birk of the Generation Group and by Joe Galdo of DOE's Office of Utility Technologies.

Taking Advantage of Real-Time Pricing

THE STORY IN BRIEF Widely offered by utilities in the United States and abroad, real-time pricing is a proven method of reducing energy costs for a broad range of commercial and industrial customers. Utilities in turn benefit directly by retaining key customers. Now EPRI is leading efforts to make RTP even more attractive to power suppliers and consumers alike. Linking automated energy management systems in customers' commercial buildings and industrial facilities to hourly price signals from the utility can be beneficial to both parties, as shown in several recent EPRI-sponsored demonstrations. With industry deregulation, as new entities like energy service companies change the way electricity is offered to customers, RTP is likely to become part of the vocabulary of more power providers, service providers, regulators, and end users.

by Steve Hoffman and Rita Renner

HUN MAY

Guests at the Marriott Marquis Hotel in New York City always enjoy their stay. All year round, the guest rooms are comfortable, the meeting rooms functional, and the ambience pleasant, with a large open atrium at the core of the building. While guests are aware of the amenities the hotel offers, they probably don't know what's behind them—a sophisticated control system that regulates everything from lobby temperature to ballroom light levels. And this building energy management system goes one step further. Linked to the local utility, Consolidated Edison Company of New York, the system receives hourly energy price signals. On the basis of this real-time pricing (RTP) information as well as operating parameters set by the building manager, the system automatically manages building energy use.

All this is done without compromising guest comfort. In fact, business at the hotel is booming, while energy costs have dropped. "Since the system was installed, we have saved about $1 million," says Ed Pietzak, the Marriott's director of engineering.

But what did these customer savings mean to Con Edison? "Offering customers the chance to be extremely energy efficient at lower costs without compromising comfort is one of our goals in working with RTP rates," says Bob Bell, vice president of R&D at Con Edison. What's more, in a state where a competitive retail energy marketplace is only a year away, the utility has developed an attractive new energy service.

"Here, the intelligent marriage of automatic control in buildings and real-time pricing is creating the kind of win-win scenario for the utility and its customers that most utilities are seeking today, given the competitive demands to retain customers while reducing costs," says EPRI's Steve Drenker, manager of the Information Systems & Telecommunications Business Area.

RTP makes sense

Real-time pricing, which features hourly based rates that reflect the time-varying cost of generating and transmitting electricity, has been around for a number of years. Only recently has it become widely offered, however. At least 30 U.S. utilities, as well as power providers in Canada, the United Kingdom, Norway, Australia, and New Zealand, make RTP rates available to commercial and industrial customers. Utilities worldwide are interested in RTP as a way to retain existing customers, attract new ones, and reduce peak generation costs. Regulators are interested in RTP, too, as a factor in the success of retail wheeling and deregulation. The real-time cost of electricity is the basis for a spot, or pool, market, in which the price of electricity is established by supply and demand. When, through retail wheeling, customers can buy their power on this spot market for the best available price, their savings can be substantial. Automated RTP control, in turn, offers these customers the chance to maximize those savings. Already available in the United Kingdom, retail wheeling is at the heart of deregulation efforts in California, Massachusetts, and New York.

Beyond these obvious benefits, many industry participants see even more advantages to RTP. This form of pricing enables better use of existing assets, including generation, transmission, and distribution, by leveling energy use; that is, it enables the assets to be operated at a higher load over a larger part of each day. RTP opens up new business opportunities with customers—a natural outcome of the closer business arrangement RTP affords. And, of course, saving commercial and industrial customers money increases customer satisfaction with their utility. Taken together, these benefits mean that RTP makes sense even for low-cost power providers. In fact, some industry observers place the potential value of RTP to customers and utilities in the billions of dollars.

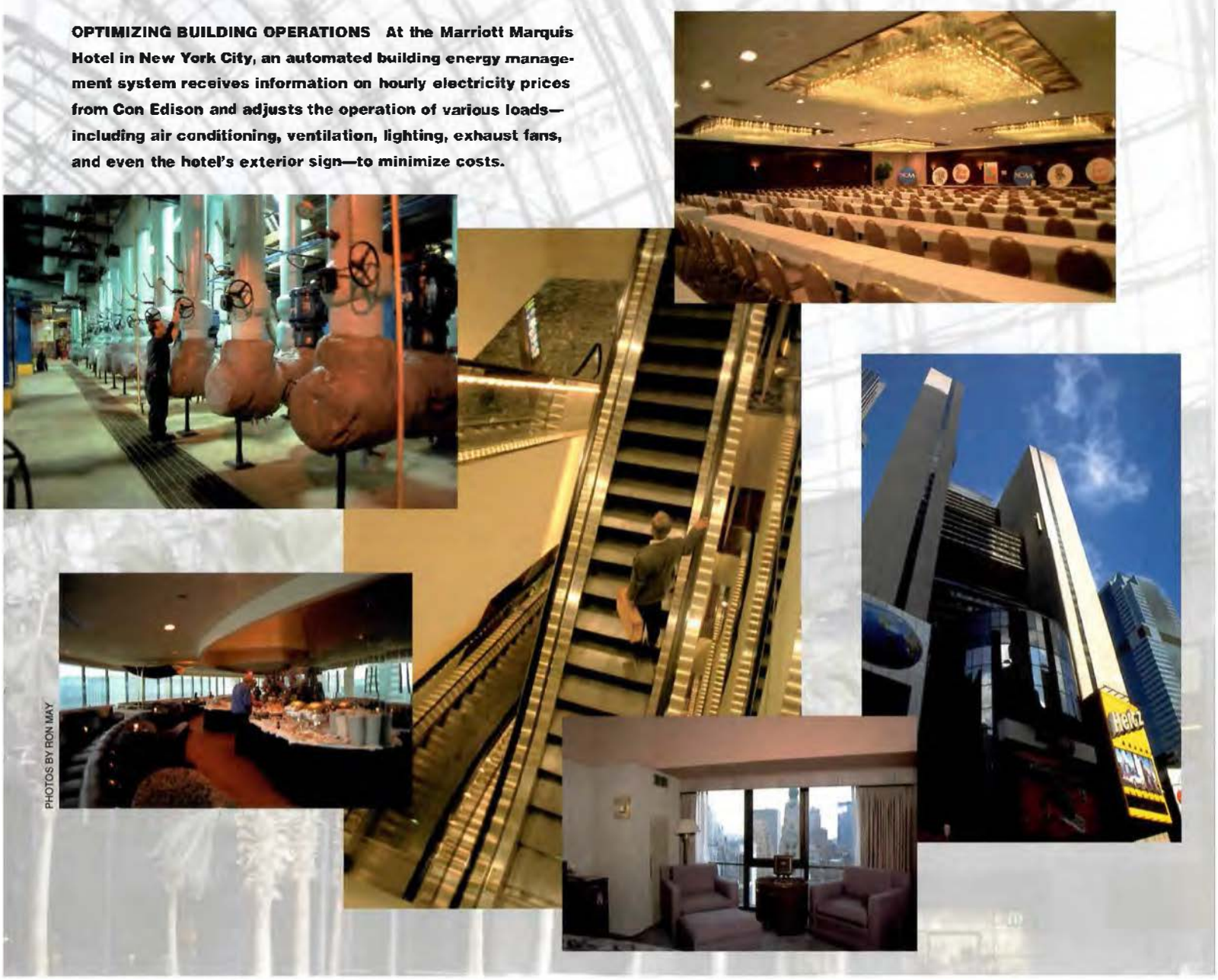
But among customers, an impediment to the widespread acceptance of RTP has been the practical difficulty of taking advantage of the rates. Energy management systems (EMSs) in large commercial buildings, such as office buildings and hotels, typically control hundreds of parameters to regulate space heating, ventilation, air conditioning, lighting, and other loads. To optimally modulate building energy use in response to hourly prices, building operators need to manually adjust scores of these parameters several times a day. Each day, control schedules detailing set points and start/stop times for HVAC equipment and lighting need to be prepared in order to take into account the hourly price the utility delivers. Even in the best-case scenario, with a dedicated operator responsible for these activities, optimizing the large number of variables for maximum savings is no easy task.

Enter automatic control. "Our team of utilities, contractors, and other research organizations has developed and demonstrated several key technologies that fully automate the process of building EMS control with RTP," says EPRI's Larry Carmichael, manager of customer interface and controls. Although the effort may seem straightforward, it actually called for a chain of new tools. Software was needed at the utility to prepare the real-time prices, a communications system was needed so that the utility could "talk RTP" with the customer, and a controller was needed at the customer site to decide how to manage loads. The Marriott Marquis application showcases the smooth integration of the new systems developed by the team, which consisted of EPRI, Con Edison, the New York State Energy Research and Development Authority (NYSERDA), the Empire State Electric Energy Research Corporation (ESEERCO), and Honeywell.

Technology chain

At Con Edison, a PC software product called the Utility Master Station handles the utility end of things. This software manages communications between the utility and the customer. It retrieves energy prices from files updated daily by the utility RTP program manager and then sends the prices and text information with messages to the customer's building EMS.

Connecting the utility computer to the customer's controller is the job of the Customer Communications Gateway (CCG), developed collaboratively by EPRI, Con Edison, and Honeywell. The CCG software provides an interface between utility networks and applications in customer-owned automation systems, including



OPTIMIZING BUILDING OPERATIONS At the Marriott Marquis Hotel in New York City, an automated building energy management system receives information on hourly electricity prices from Con Edison and adjusts the operation of various loads—including air conditioning, ventilation, lighting, exhaust fans, and even the hotel's exterior sign—to minimize costs.

PHOTOS BY RON MAY

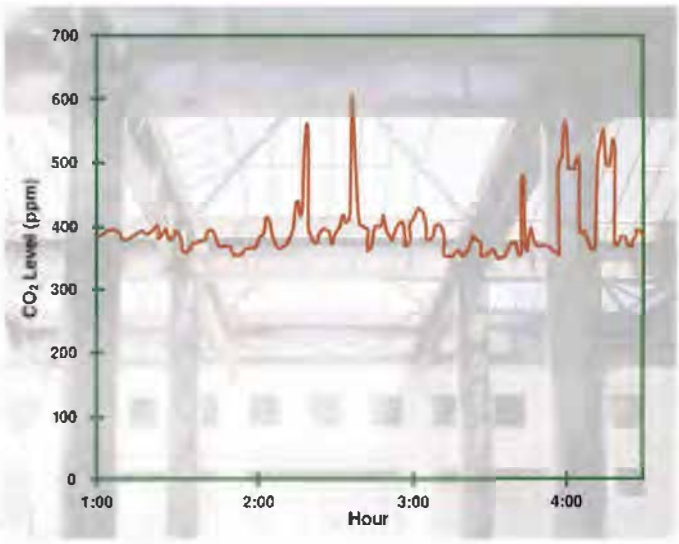
building EMSs. It complies with the Utility Communications Architecture (UCA), a standardized way of exchanging information using the Manufacturing Message Specification protocol and common object definitions, which are mapped to the proprietary controller protocols used by the customer's EMS. Operating on the customer's PC, the CCG permits the transfer of energy price schedules, meter readings, and other text information between the two parties. At Con Edison, it is receiving information transmitted over ordinary phone lines; however, because of UCA, it can easily use other communications media.

"This link, beyond its critical role in the RTP–building EMS arrangement, has a bigger job," says Drenker. "Since it allows two-way communication, the CCG can strengthen utility-customer relationships by simplifying information exchange." Obtaining valuable information on how customers use energy and what kinds of energy products and services are useful to them enables utilities to create a multitude of new services. With the CCG software, a utility can automate data collection, outage and theft detection, and meter reading, as well as offer advanced billing, innovative rate schemes, and disaggregated billing.

Completing the connection between utility prices and customer building control is the RTP Controller, which EPRI helped develop and which won the Innovation Award for best new utility customer service product at the 1996 European DA/DSM DistribuTECH Conference in Vienna. Armed with the day's prices, the controller can command up to 500 control points in a building automation system. As the day goes on, it automatically shifts electrical equipment use, turning loads on and off within the limits of the conditions specified by the building manager (see sidebar, page 21). The system can be overridden by the manager in the event of a change in operating plans.

Good investment at financial center

While the Marriott Marquis project marked the first commercial use of automated on-line control with RTP, a second effort now under way is applying the concept on a larger scale and is automating additional building systems. The World Financial Center in New York City is a huge complex of shops, restaurants, and, above all, office space. Its 8 million square feet are home to American Express, Merrill Lynch, and Dow Jones. With four office towers ranging from 33 to 50 stories tall and an atrium (called the Winter Garden) facing the Hudson River, the complex has a peak load of 45 MW. "We were eager to take advantage of the real-time rates the utility had offered," says site property manager Vince Daniele of World Financial Properties, the center's building manager.



MAINTAINING HIGH AIR QUALITY **In commercial facilities like the World Financial Center, building managers cannot sacrifice indoor air quality to save energy dollars through ventilation reduction when RTP rates are high. At the center's Winter Garden, a sensor system that measures carbon dioxide and volatile organic compounds was installed to ensure that high indoor air quality is always maintained, even during peak price periods. If CO_2 or VOCs approach preset levels, the system sends a signal that overrides ventilation control settings. (The graph shows sensor monitoring data for CO_2, for which the preset control range is 900–1000 ppm.)**

So a year ago, the RTP team members launched another large-scale project—installing technology similar to the Marriott's in the World Financial Center to control nearly half the complex's peak load. The project first automated loads in the Winter Garden, where, during lunchtime and other high-price hours, the control system slices the atrium's peak electrical load of 1.2 MW almost in half. Con Edison wins again too, by satisfying its customer and by enhancing its competitive position to offer new energy services in a deregulated environment.

A key innovation in this project involves the use of a sensor system to ensure that high indoor air quality is maintained at all times. During periods of peak energy prices, ventilation fans can be an early target for building EMS controllers because they seem less critical than air conditioning and lighting. But as ventilation is reduced, the quality of indoor air deteriorates, which can cause occupant discomfort or, in severe situations, drowsiness. To prevent this from occurring in the Winter Garden, the RTP team incorporated into the controller a sensor system that measures carbon dioxide and volatile organic compounds. Developed by Spence Associates under NYSERDA sponsorship, the system overrides ventilation control settings if CO_2 or VOCs approach preset levels. "This is the type of project that fits NYSERDA's mission of using innovative energy technologies to improve New York state's economic climate," says Mary Ann Bowers, NYSERDA project manager. "We helped bring significant energy and cost benefits to a very large state company, using a new indoor air quality product developed through NYSERDA's partnership with a small state manufacturer."

Another aspect of the World Financial Center project is even more ambitious. In addition to the load-shedding approach used at the Marriott Marquis and in the center's Winter Garden, the project team is testing another way to maximize RTP savings at the complex. Engineers are now incorporating a system for optimal control of the complex's large central-plant cooling system, which includes ten 1600-ton chillers and a 3-million-gallon chilled-water thermal energy storage (TES) system. The control system is scheduled to go on-line in time for this summer's hot days. This effort marks the first on-site real-time control of a commercial TES system. "RTP enables us to make better use of our storage equipment, and, of course, we're anticipating larger cost savings," says Nick Geannek, site electrical engineer.

Industrial automation

"Commercial customers represent only one target group for automated control with RTP," says Carmichael. "In the industrial market segment, the potential for beneficial applications is even larger." Industrial customers often can shift large discretionary loads, making them ideal candidates for RTP programs.

Automated control of industrial process systems has already begun. At Goulds Pumps in Seneca Falls, New York—a customer of New York State Electric & Gas Corporation (NYSEG)—engineers are automating the compressed-air system. A producer of centrifugal pumps, Goulds uses its multiple-compressor system to supply air to plant foundry, machining, assembly, and test operations. Automation of this system is expected to reduce the company's compressed-air operating costs by 50%. Central to this demonstration—sponsored by EPRI, NYSERDA, NYSEG, ESEERCO, Honeywell, and Plant Air Technology—is a supervisory controller that will optimally schedule the system's six air compressors in response to demand for air in the plant.

Similar in hardware and software to the RTP Controller used in the Marriott and World Financial Center applications, the controller at Goulds not only will optimize compressor operation but also will record air usage data to identify usage time and patterns for key air-consuming

processes in the plant. "Because the controller will measure departmental air usage and peak demand, each department will be held accountable for how and when the air is used," says Paul Sember, industrial plant engineer at Goulds. The controller can even help identify maintenance needs. For instance, it will monitor critical operating data, such as compressor running hours, to recommend service intervals.

While Goulds is currently on time-of-use rates, this controller provides a platform for the future addition of automated control in response to RTP. "NYSERDA is excited about the success of automated controls," says project manager Barbara Caropolo. "Using these types of technologies, we can demonstrate to New York's industrial sector how to manage energy costs for their own economic benefit."

Automating other RTP strategies

In addition to managing load shedding and TES, customers can respond to RTP signals in other ways, which become more cost-effective when integrated into an overall strategy for automated control. Fuel switching, for instance, is a method employed by commercial and industrial customers that typically entails replacing electric power with standby or emergency diesel generator power during peak periods. To maximize savings, fuel switching would automatically occur when the cost of electricity exceeds the operating cost of the nonelectric alternative. Up to now, operators have had to perform the switching operation manually, but the RTP Controller can integrate this function into a comprehensive automated control system.

Precooling, a form of load shifting, is another cost-effective component of an overall RTP strategy. Building operators customarily precool spaces such as conference rooms and ballrooms before occupancy to achieve the most comfortable temperature when guests arrive. After the space is precooled, the temperature is allowed to drift back to a higher but still comfortable setting. For instance, to prepare a hotel meeting room for a conference session scheduled for noon, the operator may begin precooling at 11:00 a.m., knowing that the space requires nearly one hour to cool to 72°F and that any cooling losses will be minimal. Electricity prices also increase sharply at 11:00 a.m., however, and the hotel may actually spend less for electricity by shifting the precooling load to 10:00 a.m. In that case, the meeting room's temperature may drift back to a higher setting between 11:00 and

Optimal Control: A Typical Day

The building management team at the Marriott Marquis Hotel in New York City, the largest member of the Marriott chain, have their hands full. The 51-story high-rise accommodates guests in 1911 rooms, seven restaurants, and a number of meeting rooms, covering a total of 1.825 million square feet. Driven by 2700 tons of cooling and other loads, the hotel's peak load can reach 6 MW, enough power for a small town. There's a lot to maintain and many people to keep happy, but one task that requires little effort is control of the building's energy management system.

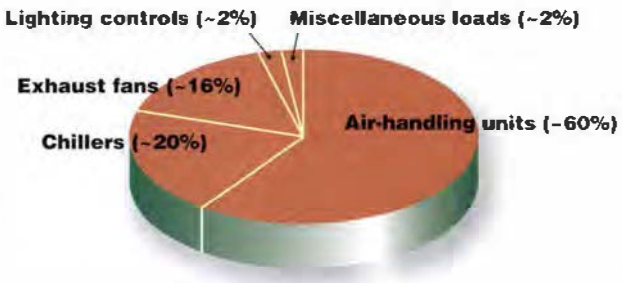
ROB MAY

TYPICALLY UNEVENTFUL **Aside from inputting daily occupancy schedules and occasionally overriding load curtailments in response to guest requests, the Marriott's assistant chief engineer and staff can usually let the RTP control system do its job automatically.**

Planning for a typical day begins in the late afternoon of the preceding day, when the building's assistant chief engineer receives the next day's schedule of hourly prices from Con Edison. (Depending on a utility's load, RTP rates can vary dramatically throughout the day, from as low as a few cents per kilowatthour to as high as $3 per kilowatthour for brief periods.) The assistant chief inputs the occupancy schedule for the ballroom and conference rooms provided by the sales department, using the RTP Controller software at a terminal in the HVAC control room. After the data input is complete, the software, having received the same prices electronically that were faxed to the assistant chief, determines in a matter of minutes the myriad of control set points and on/off schedules for the mammoth structure.

From midnight to 6:00 a.m., when prices are low, little if any building equipment operates any differently than it would have before the RTP link was installed. But as prices begin to rise in the midmorning, much is operated differently. Air-handling fans throughout the building, for example, are cycled on and off, beginning at a trigger price as low as 6¢ per kilowatthour. In fact, these fans represent the greatest potential for energy savings, since intelligent restriction of their use has a minimal impact on comfort but a big impact on cost. While this is going on, almost no intervention on the part of building staff is needed. Typically, a member of the engineering staff assigned by the assistant chief checks on the system periodically. In the event of alarms, the assistant chief is called in to investigate problems identified by the controller software or to override parameters in targeted hotel areas. Barring these activities, the lone activity is the input of scheduling information for the next day. □

noon than if precooling had started later; but precooling the room to a lower temperature to compensate for these cooling losses still costs less than precooling during the later time period. Although this method is highly site-specific and requires more operator assistance than generalized load shedding, the RTP Controller can minimize operator involvement by automating the real-time, mechanical aspects of precooling.



LOADS OF CUSTOMER SAVINGS **The automated RTP control system at the Marriott Marquis Hotel has yielded annual savings of $500,000, mainly through reductions in energy costs for air-handling units, chillers (for air conditioning), and exhaust fans; lighting and miscellaneous loads have contributed additional savings. (Data source: EPRI TR-107032)**

Broad applications

With successful demonstrations like the Marriott Marquis and the World Financial Center pointing the way, a growing number of utilities are exploring how they can maximize the energy savings of their commercial and industrial customers through RTP programs and automated control. One of these is Pennsylvania Power & Light Company. "We are pursuing a proactive approach to customer retention by offering a wide range of value-added services, one of which is RTP," says PP&L's George Beam, senior engineer, pricing. With a customer who operates a meat-processing facility, the utility is exploring the feasibility of what may be the first application of industrial RTP automation. PP&L is also considering RTP automation solutions with other industrial and commercial customers, including a pet food manufacturer and East Stroudsburg University, a 54-building, 184-acre campus with more than 5000 students.

With the nation's largest RTP program—over 200 customers strong—Georgia Power Company has already demonstrated its commitment to offering commercial and industrial customers competitive pricing. And some of its customers are taking the next step by purchasing from Honeywell the automated control system jointly developed with EPRI and others. Hartsfield International Airport in Atlanta implemented its system in time for the 1996 Summer Olympics, while Emory University's Crawford Long Hospital installed its system a year earlier—one of the first RTP-EMS applications.

Key to the success of marrying RTP with automated control systems is a comprehensive "courtship"—an investigation of candidate sites to ensure that the proper control systems are implemented. Arming utilities with the tools they need for such investigations is another focus of EPRI efforts. "To help utilities and customers more accurately predict the benefits of RTP, we're developing a database of RTP case studies called the Energy Services Information System, or ESIS," explains Carmichael. Utilities will be able to use this tool to develop cost-effective RTP automation strategies that consider the site-specific needs of candidate commercial and industrial customers.

Similar to EPRI's PQ Database, which serves as a repository for power quality case studies, ESIS will contain utility case study information from field trials and demonstrations, as well as analytical tools needed to predict how commercial and industrial customers will benefit from RTP automation. The database will include such specifics as customer end-use equipment performance profiles, end-use load history data, and case study results. The analytical tools will predict how RTP control of specific loads will affect demand, energy use, utility delivery costs, and utility benefits.

Complementary tools also under EPRI development will boost ESIS capabilities by providing highly accurate data. For instance, load monitoring will become easier than ever for both utilities and customers with the Commercial Non-Intrusive Load Monitoring System, or C-NILMS. Installed at the customer meter, this device, like its residential counterpart (already commercially available), will measure individual end-use loads and determine building and equipment energy use patterns—information helpful for ESIS analyses.

Retail wheeling

"Impending retail wheeling is sure to thrust RTP and automatic control into the limelight," says Drenker. "From the utility perspective, RTP provides a way to offer the best possible price. As opportunities open up for customers to purchase power from alternative sources, RTP will become even more valuable as a customer retention tool."

COMPARABLE PRODUCTIVITY AT LOWER COST **In an EPRI demonstration at Goulds Pumps in Seneca Falls, New York, the use of automated controls to optimize customer operations is being extended to the industrial sector. The control system at Goulds will coordinate the operation of the plant's compressed-air system, including six compressors like these, to minimize costs without decreasing productivity.**

PHOTOS COURTESY GOULDS PUMPS

Another way to retain customers is to help them help

Cool Storage and Real-Time Pricing

Like utility pumped-storage hydroelectric plants, commercial and industrial thermal energy storage (TES) systems optimize charge and discharge patterns to maximize energy cost savings while satisfying load. For commercial building cooling, chilled-water storage and ice storage are the most common TES types. Operators typically charge, or fill, the TES system with coolant at night according to a fixed schedule, and the system empties, or discharges, the coolant the following day to provide cooling during peak hours. However, operators developed these strategies with time-of-use rates (i.e., on-peak, partial peak, and off-peak rates) in mind. RTP strategies differ, since system operation must minimize costs under time-varying rates and cooling loads.

Automated RTP-based control of TES systems involves the coordination of variables not involved in load shedding. For instance, in order to accurately determine the charge/discharge schedule, the control system must predict hourly building cooling loads, using occupancy information and commercially available weather forecasts, and must have access to RTP rates for the upcoming day or two.

Research and development work on RTP automation for TES systems dates from the late 1980s, when EPRI and Con Edison cosponsored the first RTP automation project in Westchester County, New York. At the field-test site, a commercial customer used an ice thermal storage system to cool a 100,000-square-foot building. RTP signals from Con Edison were transmitted to an off-site location where the researchers' control software determined the optimal charge/discharge schedule. The customer realized energy savings of nearly 10%, demonstrating the feasibility of TES automation for RTP purposes. But a direct interface, with commercially available automated controls located at the customer's facility, was needed to maximize benefits.

RON MAY

WORLD STORAGE AUTOMATION **Integrating thermal energy storage into the mix of controlled loads can substantially increase RTP benefits for both customers and utilities. Optimizing the operation of the World Financial Center's ten 1600-ton chillers and 3-million-gallon chilled-water storage system will begin this summer. In response to each day's schedule of hourly electricity prices, the control system will charge the chilled-water storage system during lower-price hours and tap into it for peak-time space cooling.**

To meet this need, researchers explored various control capability enhancements in a 1996 study conducted by EPRI, Honeywell, and Pacific Gas and Electric Company for the San Francisco Marriott Hotel. The study resulted in a conceptual design for an enhanced RTP-based supervisory controller, the precursor of the Honeywell controller being installed at the World Financial Center. □

themselves. To do this, energy service companies (ESCOs) can provide services that help customers combine automatic control with the RTP offering. For example, an ESCO may purchase and install control equipment for a customer, who then pays off the equipment with energy cost savings. The EPRI demonstrations have proved that a one-year payback period or less will be typical.

From the customer perspective, retail wheeling means the opportunity to purchase power priced at time-varying levels from a variety of sources, including a spot market. Automatic control enables customers to make the best use of this market for hourly or even half-hourly priced power. Conceptually, each of the technologies in the chain from the power supplier to the customer can accommodate multiple blocks of real-time prices from multiple sources.

Imagine a large industrial customer planning the production of a new product, or a property development firm with a new commercial retail and office complex for lease. Both of these customers could decide to meet their baseload power needs through long-term fixed contracts. The industrial customer might choose to satisfy load required for firm production orders, and the property developer load required for committed space, by purchasing long-term firm or curtailable power at near-wholesale rates. However, either customer might then choose to make additional purchases on the retail spot market as a hedge against business fluctuations. The RTP Controller could be used to optimize power utilization under these multiple-tariff structures. Also, because of the more precise load control possible with the controller, customers could minimize the purchase of so-called ancillary services, such as load-following and energy imbalance services, from a transmission company.

Beyond the 30 utilities that currently offer RTP rates, at least another 30 are investigating the RTP option. And with the onslaught of deregulation, clearly RTP is here to stay. But the key to the win-win scenario for this innovative rate structure is the automatic control system behind it. ■

Background information for this article was provided by Steve Drenker and Larry Carmichael of the Customer Systems Group and by John Flood of Utility Consulting Service.

TAG:

On-Line Resource for Cost & Performance Data

ILLUSTRATION BY LARRY GOODE

THE STORY IN BRIEF Industry restructuring and emerging competition are bringing major changes in the way companies in the electricity business conduct planning studies, including those that require detailed cost and performance analyses of multiple technology alternatives. These changes will be key to the future role of a longtime critical information and analytical resource for EPRI members: the Technical Assessment Guide, the core of which is now delivered electronically through a server computer. Building on a solid record of value to utilities for resource planning and technology screening, the guide is evolving to provide users with new features and analytical tools designed for a more competitive energy market.

by Taylor Moore

One of EPRI's most enduring, yet largely unheralded, products—an essential information and analytical resource for member utilities over the past 20 years—is leading the way to a future of electronic delivery of EPRI software. The product is the Technical Assessment Guide, or TAG®, which is evolving from a series of hard-copy technical reports into a powerful, integrated package of server-based programs for PCs with Windows operating systems.

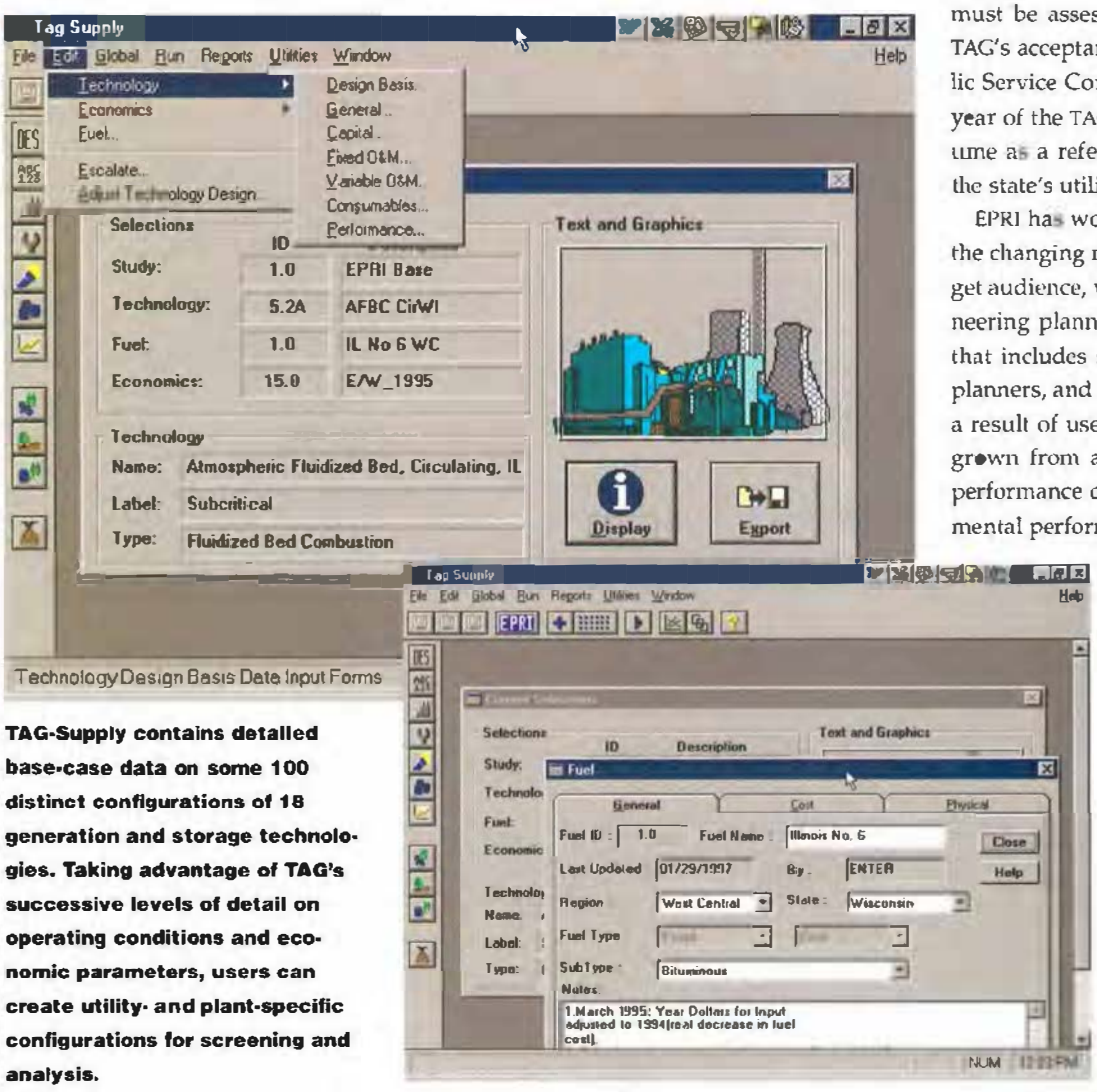
Originally a single volume, TAG was developed during the Institute's formative years as an in-house tool that provided a consistent basis for evaluating the economic feasibility of R&D alternatives for electricity supply technologies. The guide was first published for use by member utilities in 1977 and soon gained a reputation for authoritative information on the cost and performance of various conventional and advanced generation and environmental control technologies. Today TAG encompasses a multiedition series of EPRI reports including cost and performance data for generation and storage technologies (TAG-Supply™) and for distributed resources (TAG-DR); a resource book on economic evaluation methodology (TAG: Fundamentals and Methods); and descriptive materials on end-use technologies.

Widely known by its acronym throughout the utility industry and the energy regulatory and research communities, TAG has become a de facto standard reference guide for calculating capital costs, fuel costs, performance, and other technical and economic characteristics for various supply and storage technologies. It covers 18 technologies with nearly 100 distinct configurations of process technology, fuel, and geographic location. The technology categories include all major fossil and nuclear plant types and configurations, several energy storage technologies, and some renewable generating options like wind and biomass.

For years, utility planners and engineers have relied on TAG's data and screening capabilities to identify and rank potential resources for new electricity supply. TAG calculations and supporting analysis are often included in rate filings with state utility regulatory commissions; recently, they have formed the backbone of many utilities' mandated integrated resource planning (IRP) exercises, in which both supply- and demand-side technologies must be assessed. A notable example of TAG's acceptance was the Wisconsin Public Service Commission's designation last year of the TAG distributed resources volume as a reference document for use by the state's utilities in commission filings.

EPRI has worked to identify and satisfy the changing needs of TAG's principal target audience, which has shifted from engineering planners to a much wider group that includes strategic planners, resource planners, and environmental planners. As a result of user demand, TAG-Supply has grown from a purely cost and technical performance database to include environmental performance information, technology maps for emerging technologies, and computational algorithms for customizing cost and performance data to site- and user-specific conditions.

As TAG-Supply grew in size and complexity, the challenge of keeping the hard-copy edition up-to-date became overwhelming and spurred the development of the first electronic version, which became available on the EPRI mainframe comput-



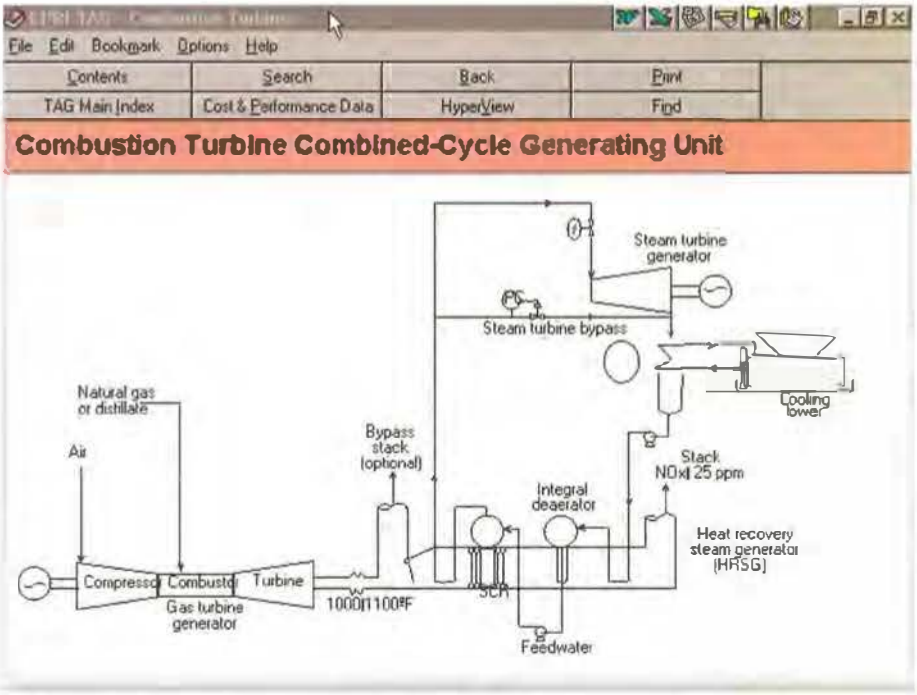
TAG-Supply contains detailed base-case data on some 100 distinct configurations of 18 generation and storage technologies. Taking advantage of TAG's successive levels of detail on operating conditions and economic parameters, users can create utility- and plant-specific configurations for screening and analysis.

er in 1989. The spreading use of PCs among utilities in the early 1990s led to the initial PC version (DOS) in 1991. Available only to EPRI members, the TAG-Supply software was first installed on a server at the Institute in 1993 with dial-up modem access for more-timely updates and direct downloading of data.

The move by PC users to Windows operating platforms has led to the present user-friendly Windows-based version of TAG-Supply, now in limited distribution following the completion of beta testing last fall. This new electronic version incorporates application programs for managing the TAG database, calculating capital and operating and maintenance (O&M) costs, and estimating total revenue requirements, carrying charges, discounted cash flow, and levelized busbar production costs.

TAG-Supply's transition to a Windows 95/NT operating platform (compatible with Windows 3.1) makes the software a launch click away from running on even the latest, most powerful business computers. And it enables users to export TAG data to application programs like Word and Excel to produce customized reports. Moreover, TAG's server-based delivery platform could well become the model for future electronic distribution of other EPRI software and technical reports. The server not only minimizes the cost of distribution and of updating information but also helps protect—through password access—the proprietary value to EPRI members of the intellectual property embodied in TAG's extensive databases.

Plans are now being developed to produce an electronic, updated version of TAG's distributed resources volume in the next year or so. TAG-DR could play an increasingly important role in helping utilities evaluate the comparative economics of resource and asset management alternatives at both utility sites and customer locations. In addition to presenting design, cost, and performance information on a suite of generation and storage technologies that can be used in distributed generation applications, TAG-DR discusses the impacts of distributed resources on utility distribution systems. With TAG-DR, resource and asset management tools based on the methodologies developed for IRP are brought to distribution planning.



Technical reference and background material, including process flow diagrams, can be viewed and also exported to other software for producing customized reports. Shown here is a diagram of one configuration of a combustion turbine combined-cycle plant—a supply technology that is currently the focus of extensive cost and performance analysis.

Successful transition

"TAG is one of the original EPRI products for utilities that has successfully made the transition from paper to electronic form," says Charles Siebenthal, manager of the strategic assessment department in Strategic R&D at EPRI. "The earlier versions of TAG, particularly the supply and end-use volumes, have quietly returned many times the value of their original development costs to member utilities over the past 20 years by greatly shortening the time required—and eliminating the need to hire contractors—to prepare reliable, accurate economic evaluations of new electricity supply options or of bids for purchased power. But as the electricity business becomes more competitive, the community of utility users of TAG is changing, and the ways that utilities will derive competitive value from TAG resources will also change. TAG will have to continue to evolve in order to meet the analytical needs of utility planners and marketers in a more competitive environment."

In some cases, power marketers are already beginning to use TAG for competitive analyses that are quite different from the comparative screening studies typically performed by traditional planning and engineering users, notes Gopalachary Ramachandran, EPRI team leader for technology assessment. "Some power-marketing people are using TAG to evaluate bids for wholesale power purchases. They can ask a bidder for details about the basis of a bid and then use TAG as a reference check to gauge the bid's reasonableness, especially if the bid is based on a new plant."

As Ramachandran points out, TAG-Supply allows users to customize features or adjust parameters to regional as well as to company- and plant-specific conditions, making the software very flexible for various types of analysis. "Its ability to provide the user with specific details at several different levels helps explain TAG's popularity with utilities—planners can use

it to survey broad categories of technologies quickly, whereas an estimator or engineer can look deeply into the technical details of individual technologies."

TAG's financial analysis programs have already found an expanding user audience. The programs can calculate standard revenue requirements for projects involving regulated utilities or can use the discounted-cash-flow methodology, which is more applicable for unregulated power producers or projects.

With a scope of analysis and information that encompasses virtually the full spectrum of EPRI R&D, the TAG product series represents the collective efforts and contributions of over a dozen research managers and technical specialists over the years. "The new Windows version of TAG represents an upgrade of our technology delivery platform that increases the guide's value to its users," says Gail McCarthy, director of Strategic R&D.

Need for continuing support

"Making TAG available in electronic form is a direct response to the challenge of finding new and useful ways to synthesize the voluminous data in EPRI reports and present it clearly in a concise format," says Siebenthal. "The electronic medium also enables users of TAG information to customize the database and provides new desktop capabilities for evaluating technologies."

The move to electronic form parallels a shift in how the TAG product series fits into EPRI's funding structure, now disaggregated to the target level. This shift, in turn, reflects how TAG's role among utility users is expected to change, as an emerging competitive energy market replaces the regulatory model under which IRP was previously conducted.

Although most formal utility IRP exercises are being eliminated in anticipation of industry deregulation, utilities will still have a need for corporate resource planning studies of comparative technology economics. In a more competitive environment, information will become more crucial than ever for crystallizing strategic options and identifying the critical strengths and weaknesses of competitors' business plans and proposals, which in turn link directly to plans for using new technology.

Through 1995, TAG was entirely funded by the Institute's core R&D programs for use in independent economic and technical evaluations of specific technologies and products that were a focus of EPRI's technical business groups. The principal elements of TAG were available to all EPRI members. In 1996, the majority of funding for updating the TAG-Supply database was tailored collaboration funding provided by the 20 utility members of the TAG-Supply Users Group. This year, almost all the funding for technology updates will be provided by the users group. Also this year, certain new features and enhancements, such as future updates of TAG-DR and its planned shift to electronic form, are being funded under EPRI's distributed resources target. Enhancements to TAG-Supply and TAG-DR are designed to increase their competitive market analytical capabilities and will be available only to members providing the funding, either through tailored collaboration or through target funding.

As several utility users of TAG-Supply point out, the value their companies get from having access to the most current TAG data and calculation capabilities has been worth the additional funding support required for users group membership.

The timeliness of TAG data is important to Carolina Power & Light Company in evaluating bid responses to requests for proposals for additional peaking capacity, says Jennifer Whaley, a senior analyst in resource planning at CP&L. "It's very important to have reliable data when comparing generic alternatives for future resources, and we use TAG as our database for generic resources," she explains.

Several calculation and analysis functions that previously had to be done separately, Whaley notes, are now performed by TAG-Supply: developing generic cost and performance estimates; calculating annual carrying charges and total plant investment cost; estimating annual busbar production costs; and graphing levelized

TAG-Supply provides extensive coverage of the components of capital and O&M costs for specific technology configurations. For example, it can calculate the interactive effects of various capital cost categories and O&M costs. Even local hourly labor rates can be entered as custom parameters. Financial reports include standard revenue requirement projections and discounted-cash-flow projections.

Users Testify to TAG's Value

TAG's longevity as an EPRI product series has resulted in a solid record of documented savings and benefits among a chorus of supportive utility users. Some of the more prominent examples have occurred since TAG-Supply was placed on a server in Palo Alto four years ago.

At Southern Company Services, TAG-Supply significantly reduces the time needed to customize cost and performance data for the utility's annual technology screening process. Since TAG's development, SCS has used the guide as a starting point to identify candidate options for the company's annual resource plan; now the computerized version of TAG-Supply provides immediate, direct access to technology data that previously had to be obtained manually from a printed report. SCS planners can quickly develop data for their specific needs and can compare the economics of various options in the utility's own format. "Because EPRI has reviewed the TAG-Supply data, we have confidence in TAG's comparisons of new generation technologies' performance and cost," says Fred Ellis of SCS.

The utility holding company Entergy projected five-year savings of $70,000 from reduced planning time and avoided consultant costs through the use of TAG-Supply for its initial technology screening activity. Using TAG-Supply cost and performance data to develop a customized database, Entergy planners were able to analyze a variety of technology choice scenarios and calculate busbar cost data for the most promising options. Combining this information with in-house software, the analysts compared costs in dollars per kilowatt and cents per kilowatthour to select technologies for further evaluation. "In our least-cost planning process, the computerized TAG cut the time necessary to generate initial cost data for a range of supply-side resource options," says Entergy's Robert McQueen.

Public Service Company of New Mexico estimates that TAG-Supply's database and comparative analysis capabilities saved some $250,000 in developing a corporate resource planning process. "TAG data and reports formed the basis of the supply-side analysis volume we prepared in 1995, when it appeared we would be required to file an integrated resource plan with the New Mexico Public Service Commission," says the utility's Mark Harlan. "TAG saved us from having to hire a consultant to develop a planning process and prepare an IRP. Although it turned out we were not required to file an IRP, the volume we prepared using TAG was later filed with the commission in connection with a pending request for power purchase."

The Tennessee Valley Authority estimates that its use of TAG-Supply saved it $50,000 to $100,000 in one-time consulting fees for developing benchmark cost and performance data and through avoided staff time and additional software purchases for calculating TVA system-specific cost and performance data. Texas Utilities estimates saving approximately $200,000 a year in consulting costs for compiling similar benchmark data on supply-side options. Duke Power, meanwhile, estimates saving about $25,000 annually in consulting fees, based on past experience, by using the on-line version of TAG-Supply to quickly tailor TAG data to Duke's regional characteristics and specific plant sizes.

Planners and engineers are not the only utility specialists who obtain value from TAG. At GPU Service, when environmental staff are called on to help planners evaluate and recommend resource options, they use TAG to incorporate economic data into their analysis of a wide range of technology options and fuel use scenarios, saving an estimated $50,000 in consulting costs annually. Says GPU's Dennis O'Regan, "TAG-Supply walked me through the process of determining costs for technology and fuel choices and helped me understand the basis for the planning staff's recommendations." □

and annual busbar production costs at specified capacity factors for various plant types and configurations. "TAG is a company resource for technology costs that saves us from having to collect the data ourselves," she adds.

TAG-Supply's ability to break out fixed and variable components of O&M costs was noted by Whaley and by James Hall, a generation specialist at the Tennessee Valley Authority. Hall says that in 1994 and 1995, when TVA conducted its own IRP exercise, TAG's detailed data on O&M costs for generating technologies not in use by TVA proved particularly valuable: "Not only does TAG have reliable capital costs for nearly 100 different supply options, it also contains O&M cost data that are not easy to come by for some options. TVA had data for its own plants, which are mostly pulverized coal, nuclear, and hydro. But we didn't know much about variable versus fixed O&M costs for plants like combustion turbine combined cycles or pressurized fluidized-bed units. We were able to dig into the depths of the TAG-Supply database and determine our own perspective on these costs."

TAG-Supply also provides value to members through its reliable capital cost and O&M data for emerging technologies, with which few utilities may have direct experience—for example, various fluidized-bed combustion systems, fuel cells, and wind turbines. "We spend most of our time on what are our key front-burner technologies—the ones in use today—and we use TAG as a backup check for those calculations," says Hall. "But for other options that are further out and for which we can't spend much time producing customized estimates, TAG is a good information resource."

Fred Ellis of Southern Company Services says he also relies on TAG-Supply for cost and performance characteristics of supply options with which Southern Company's operating utilities—Alabama

Power, Georgia Power, Gulf Power, Mississippi Power, and Savannah Electric—have no direct experience. Ellis eagerly anticipates switching to the Windows version of TAG-Supply this year "because it's going to be more user-friendly and will have some new features that I'd like to use." He says that although he is probably the only current user of the electronic version of TAG at SCS, "there are a lot of people at Southern who still have and still reference the 1993 hard-copy version."

Ellis says that he was able to demonstrate value justifying SCS approval for its initial two-year membership in the TAG-Supply Users Group. But with TAG's changing role in utility business use and with the continuing pressures to critically evaluate recurring expenses, he notes, TAG must prove its worth to the company again every couple of years, when users group membership comes up for renewal.

"The world is changing, and a lot of what we depended on TAG for in the past, like IRP support, may have less emphasis in the next few years," Ellis explains. "Activities will move from traditional TAG uses, such as for public service commission filings, toward the identification of investment opportunities in the competitive generation business. The challenge for TAG will be to fit into the new business environment of the future."

Adds Mark Harlan, technology analysis coordinator for Public Service Company of New Mexico, "TAG is a tool that's been extremely valuable to the utility industry for so long that I can't believe its value will diminish in the future, although I don't know exactly the specific ways that value will be realized."

Within the TAG-Supply Users Group, says Ellis, "there is likely to be more consideration for protecting individual company business plans. But we see TAG as a tool, and the competitive edge comes from how we use the tool—not from its development per se. We're all trying to find ways to leverage expenditures in this era of cost-consciousness by developing a product that users group members can help pay for. The competitive advantage is going to come from how a particular utility uses the information. EPRI generates a lot of good information, but only an innovative, aggressive utility will be able to take advantage of it in the competitive environment we're entering."

Concludes Ellis, "I believe TAG will continue to have a place; however, we are going to have to develop tools and applications with TAG to address the new issues that competition brings. We are interested in this to the extent that we can do it and leverage our R&D money without compromising our competitive position."

Members interested in the electronic versions of TAG-Supply and TAG-DR should contact EPRI's Ramachandran, (415) 855-2722, or Siebenthal, (415) 855-2170. ■

Further reading

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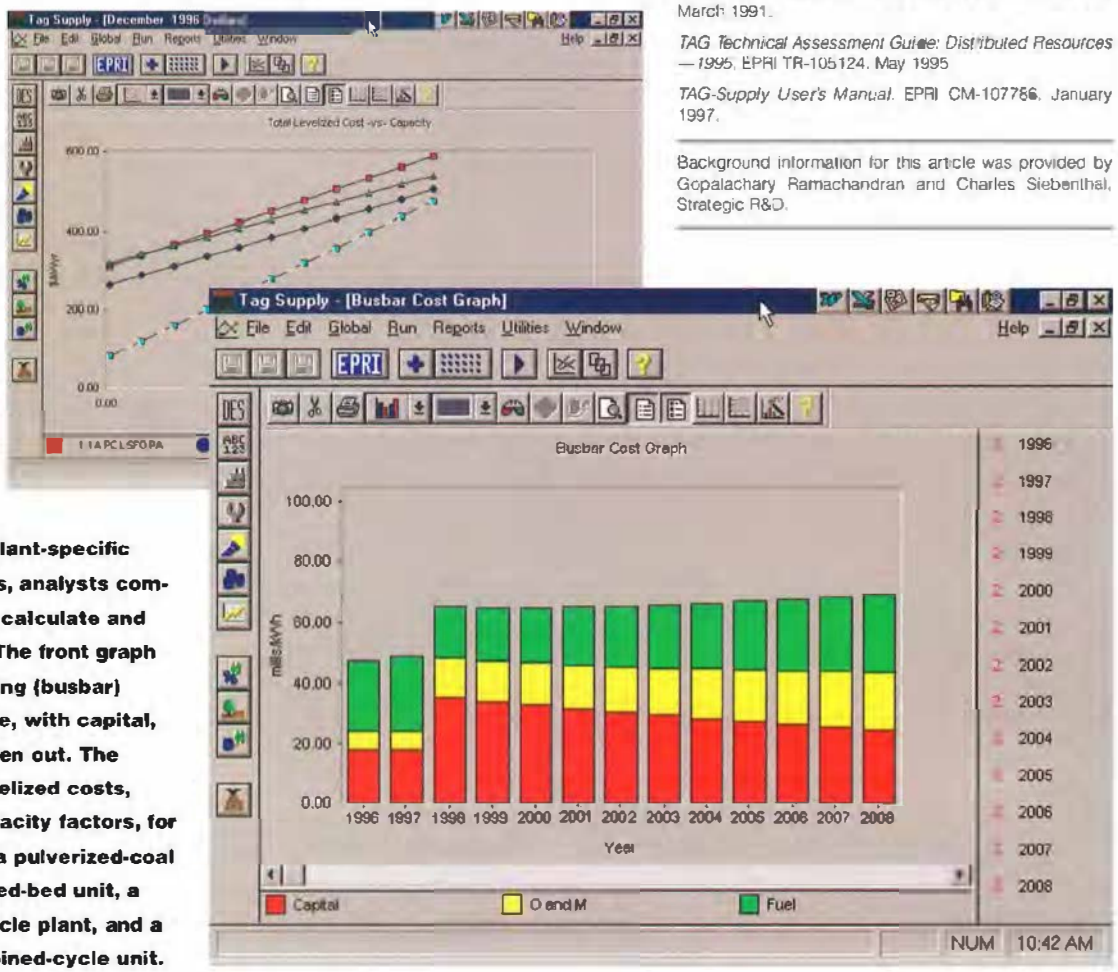
TAG-Supply User's Manual. EPRI CM-107756. January 1997.

Background information for this article was provided by Gopalachary Ramachandran and Charles Siebenthal, Strategic R&D.



After creating utility- or plant-specific technology configurations, analysts commonly use TAG-Supply to calculate and compare cost variables. The front graph shows projected generating (busbar) costs for a plant over time, with capital, O&M, and fuel costs broken out. The back graph compares levelized costs, across a full range of capacity factors, for four technology options: a pulverized-coal unit, a pressurized fluidized-bed unit, a gasification–combined-cycle plant, and a combustion turbine combined-cycle unit.

CONTRIBUTORS

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Utility Customers Go for the Green (page 6) was written by Leslie Lamarre, *Journal* senior feature writer, with background information from **Terry Peterson** and **Jim Birk** of EPRI's Generation Group and **Joe Galdo**, a program analyst with the U.S. Department of Energy's Office of Utility Technologies.

Peterson, manager for solar power and green pricing, came to EPRI in 1986 after eight years with Chevron Research Company, where his work included research on thin-film and other solar cells. Earlier Peterson was a staff scientist in the Materials and Molecular Research Division of Lawrence Berkeley National Laboratory. He has a BA in physics from the University of California at San Diego, an MA in physics from the University of California at Berkeley, and a PhD in materials science and engineering, also from Berkeley.

Birk is EPRI's manager for renewables and hydro. After joining the Institute in 1973 as a project manager for advanced battery development, he assumed increasing levels of responsibility in the areas of energy storage, hydropower, and renewable technologies. His earlier experience includes seven years as a senior scientist at Rockwell International Corporation. Birk received a BS in chemistry from Iowa State University and a PhD in analytical chemistry from Purdue University. ■

Taking Advantage of Real-Time Pricing (page 16) was written by science writers Steve Hoffman and Rita Renner, with assistance from two members of EPRI's Customer Systems Group.

Larry Carmichael is manager of customer interface and controls R&D in the Information Systems & Telecommunications Business Area. He joined EPRI in 1985 after two years as a project manager at Science Applications International Corporation. Earlier he was a project manager at Systems Control and worked as a principal engineer at General Electric Company's nuclear utility operation in San Jose, California. Carmichael holds a BS in chemical engineering from the University of California at Berkeley and an MS in mechanical engineering from Stanford University.

Steve Drenker manages the Information Systems & Telecommunications Business Area, established in 1996 to develop advanced technology to support two-way communications between electric utilities and their customers. Previously he directed the Power Quality & Information Technology Business Unit, and still earlier he managed research on fluidized-bed combustion. Drenker came to EPRI in 1978 from Babcock & Wilcox Company, where he held startup and troubleshooting responsibilities for fossil power plants. He received a BS in mechanical engineering from the University of Missouri and an MBA from the University of Santa Clara. ■

TAG: On-Line Resource for Cost and Performance Data (page 24) was written by Taylor Moore, *Journal* senior feature writer, with assistance from two members of EPRI's Strategic R&D staff.

Charles Siebenthal, manager for strategic assessment, came to EPRI in 1987 as a project manager for engineering and economic evaluations of advanced power generation technologies. Later he managed the fluidized-bed combustion program. Before joining EPRI, Siebenthal was chief process engineer for the R&D operation of the Bechtel Group. Earlier he was process development manager with the environmental engineering firm Metcalf & Eddy and worked at Shell Development Company in R&D management and engineering for petrochemical production, synthetic fuels processing, and pollution control. He earned a BS in chemical engineering from Washington University and a PhD in the same field from the University of Minnesota.

Gopalachary (Ram) Ramachandran is team leader and manager for technology assessment in Strategic R&D. Since joining EPRI in 1987, he has managed the Technical Assessment Guide, including TAG-Supply and TAG-DR (distributed resources), with the assistance of various other EPRI staff. Before coming to the Institute, Ramachandran held project management and staff positions with Atlantic Richfield and SRI International. He received a BS in chemical engineering from the University of Madras in India, an MS in chemical engineering from the University of Idaho, and an MBA from Pepperdine University. ■

Electronic Communications

EPRI-Oracle Pact Puts Utilities on Information Fast Track

EPRI has entered a business agreement with Oracle Corporation—the world's second-largest software developer—that will help ensure that EPRI members get the maximum benefit from today's most advanced communications technologies.

The EPRI-Oracle team is a strong one. As David Cain, EPRI's manager of the alliance with Oracle, puts it, "They know information technology; we know utility technology." Drawing on the symbiotic expertise of the two organizations, the alliance's first effort involves the widely anticipated network computer (NC), to be released this spring. EPRI will help develop a special version of this Internet-linked device that will include capabilities for energy management, home and business automation, security, and other functions to help utilities generate new revenue while building customer satisfaction and brand loyalty.

But the NC is just the beginning. Other Oracle technologies will be adapted to the electric power industry to support utility activities ranging from internal data management to market analysis. Oracle has already released a prototype system for utilities called Sambuca, a powerful electronic tool for companies facing competitive markets. With Sambuca, these companies can identify new revenue opportunities and determine which customers are their most valuable ones. EPRI and Oracle will work together to refine this product to better serve electric utility needs.

The new business relationship will also allow EPRI's best software products to reach broader markets.

■ *For more information, contact David Cain, (415) 855-2112.*

The network computer—which provides Internet access through a television screen—will have energy management capabilities, thanks to a collaboration between EPRI and Oracle Corporation.

DON ROPER PHOTOGRAPHY

Distributed Generation

Co-ops Get Hands-on Fuel Cell Experience

A portable phosphoric acid fuel cell has begun to make the rounds at rural electric cooperatives across the country. The 200-kW, trailer-mounted fuel cell was hooked up late last year at its first site—a baby-clothing manufacturing plant in Jackson, Georgia, that is a customer of Central Georgia Electric Membership Corporation. The fuel cell, jointly owned by EPRI and the National Rural Electric Cooperative Association (NRECA), will supply around-the-clock power to the Springs Industries textile plant for one year while engineers at Central Georgia and Oglethorpe Power Corporation closely monitor its performance. Afterward, the fuel cell will travel to co-ops in Colorado and Alaska, serving one year at each of three more sites.

Fuel cells, which convert fossil fuels to electricity without combustion, are of particular interest to rural electric cooperatives. Co-ops own more miles of distribution line per customer than any other type of utility, and they face the challenge of delivering power to remote areas as well as responding to the sometimes burgeoning growth of formerly sleepy rural communities. Since fuel cell technology is modular and clean, it offers a way to place capacity close to or even at a customer's site, minimizing the need for new distribution lines. Having the capacity on-site offers the added advantage of high-quality power that will not be disrupted by disturbances on the distribution system, such as outages caused by downed trees and lightning strikes.

There are other advantages too. For instance, hot water generated by the natural-gas-fired fuel cell now in place at the textile mill in Georgia is being used in the manufacturer's dyeing and washing processes.

The first fuel cell technology to become

The traveling fuel cell being installed at a baby-clothing manufacturing plant in Jackson, Georgia.

commercially available, phosphoric acid fuel cells have been on the market for only a few years. About 110 have been built and shipped. Of these, about 40 are installed and operating in the United States, about 30 are being used in Japan, and another 12 are up and running in Europe. The remainder of the purchased units are scheduled to be deployed soon. Other fuel cell technologies, such as molten carbonate and solid oxide, are in earlier stages of development.

The 200-kW EPRI-NRECA unit was manufactured by ONSI of South Windsor, Connecticut, a subsidiary of International Fuel Cell Corporation. After its yearlong stint in Georgia, the unit will travel to Delta-Montrose Electric Association, a distribution cooperative served by Tri-State Generation and Transmission Association of Denver. Then it will go to Chugach Electric Association in Anchorage. Its final destination is another co-op in Alaska, Naknek Electric Association, which will use it to supply power to King Salmon Air Force Base and the community of Naknek. That cooperative will have the option of buying the fuel cell after its yearlong service there.

"The intent of this project is to give the rural electric community experience with a new, emerging technology that can help co-ops meet their customers' needs," says John O'Sullivan, EPRI's manager for the project.

■ *For more information, contact John O'Sullivan, (415) 855-2292.*

Human Health

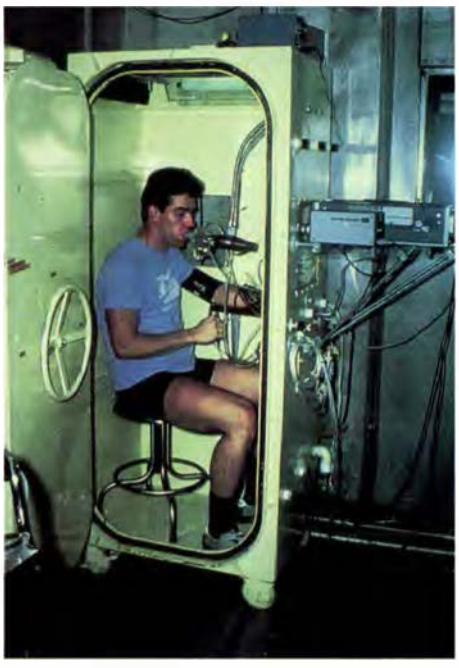
Portable Device Will Give Better Data on Inhalation

Our current understanding of the amount of outdoor air pollutants that individuals actually inhale is based on surprisingly limited data. This amount depends both on the ambient concentration of pollutants and on the individual's breathing rate.

The information currently available on pollutant inhalation was collected through an arduous process involving dozens of volunteers and lots of bulky monitoring equipment. With tubes hanging from their noses and wires from their chests, the volunteers typically ran treadmills at various speeds. Experts have used the resulting data to extrapolate exposure to pollutants for average individuals performing a variety of activities from mowing the lawn to playing tennis. As Kris Ebi of EPRI points out, the resulting data do not provide direct answers. "The extrapolation from running to resting is not very linear," Ebi explains. "Walking or running is different from mowing the lawn, and breathing rate varies by activity."

Ebi is overseeing a research project aimed at developing a better method for obtaining inhalation data. With EPRI funding, researchers at the Memorial Hospital of Rhode Island are creating a prototype of a noninvasive, portable instrument for tracking human ventilation rates—a device that, in its final form, should be small enough to clip onto a child's belt. The device is being designed to be worn by volunteers of all ages as they go about their daily activities in a variety of outdoor settings. A far cry from the cumbersome equipment used in earlier laboratory treadmill sessions, this device will provide much more realistic results—far more easily. The prototype is expected to be completed by late 1998.

■ *For more information, contact Kris Ebi, (415) 855-2735.*



A volunteer in an exposure chamber, geared up to provide resting-rate inhalation data via traditional measurement techniques.

First Written-Pole Motor Application Reaping Rewards for Stockyard

A 40-hp single-phase Written-Pole™ motor has been installed on a livestock-watering pump at a Kansas stockyard by Westar Energy, an unregulated subsidiary of Western Resources. The installation is the first application of this new motor technology, which offers utilities an opportunity to expand their markets in single-phase service areas without the expense of constructing new three-phase distribution lines. The motor, which represents 32 kW of new load for Western Resources, was identified by Westar engineers as the most cost-effective way for the utility customer, Ward Feedyard, to pump water to a feedlot from a well 3 miles away.

Written-Pole motor

In many remote areas, there is potential for load growth as a result of increasing demand for larger motors in agricultural irrigation and other water-pumping operations. But the prevalence of single-phase service in such areas, together with low load factors and low customer density, presents a challenge to utility market expansion. Conventional motors for use with single-phase service are typically limited in size to 16 hp. The Written-Pole technology—developed collaboratively by EPRI's Customer Systems Group, several utilities, and Precise Power Corporation—makes larger single-phase motors possible because it significantly reduces motor startup current requirements. The lower starting currents and higher operating efficiencies of Written-Pole motors also reduce waste heat, which results in longer motor life—up to twice that of conventional single- or three-phase motors.

Ward Feedyard anticipates that use of the Written-Pole pump motor will yield a 5% increase in livestock-feeding efficiency and a 10% reduction in veterinary costs, for total annual savings of $112,000. Western Resources estimates that over the next 30 years, the installation of such motors in its single-phase service areas could lead to increased revenues of $6.5 million (present value). Kansas, with its many agricultural irrigation operations and oil fields, is ideal for the widespread use of Written-Pole motors.

Precise Power's single-phase Written-Pole motor is currently available in sizes up to 100 hp. Higher-horsepower and medium-voltage Written-Pole motors are being developed; a field demonstration of a low-voltage 500-hp three-phase unit is scheduled for this year. EPRI is continuing R&D on advanced motors and adjustable-speed drives through a target in the Power Electronics End-Use Systems Business Area of the Customer Systems Group.

■ *For more information, contact Ben Banerjee at EPRI, (415) 855-7925, or John Roesel or Richard Morash at Precise Power Corporation, (813) 746-3515.*

TU Electric Saves on Fossil Plant Maintenance With Streamlined RCM

To deal with reduced plant operating budgets, utilities need new maintenance planning methods that optimize unit availability and cut costs. A number of utilities now use reliability-centered maintenance (RCM) techniques, primarily in nuclear power plants, to identify preventive maintenance tasks for critical components. To make RCM cost-effective for fossil power plants, however, a streamlined approach adapted to the technology's specific characteristics is needed.

Drawing on techniques used at nuclear plants, EPRI is supporting the development of such a streamlined process—called SRCM—optimized for fossil plant maintenance. With the new methodology, utilities can determine the effects of equipment failure on power production capability, safety, and cost at fossil plants and then identify the maintenance tasks necessary to ensure desired system performance. SRCM will help utilities establish maintenance programs that focus on functionality and criticality, define levels and types of maintenance to be performed (with an emphasis on predictive maintenance), and optimize the allocation of plant maintenance budgets.

TU Electric and EPRI selected three of the utility's fossil power plants at which to apply the SRCM methodology: the lignite-fired Big Brown steam station, the gas-fired Lake Hubbard steam station, and the Morgan Creek station, which

has gas-fired steam and combustion turbine units. The stations had different levels of existing preventive maintenance activity, and different systems were selected for analysis at the plants.

The project recommendations, the product of collaborative evaluations by EPRI contractors and TU station personnel, were based on historical experience with the plant equipment and on the criticality of the various components of the systems being analyzed. As a result of using the SRCM approach at the three stations, TU Electric has identified unnecessary preventive maintenance tasks with a total annual labor value of over $229,000. Taking advantage of the time saved on those tasks, existing plant maintenance staffs can focus on the equipment identified in the project as the most critical. In a follow-up effort, the Big Brown station has budgeted for a contract analyst to perform additional SRCM evaluations of plant systems.

Software developed by TU Electric during the project has been made available for use at all the utility's fossil power plants. Plans call for SRCM training classes to help TU personnel perform in-house evaluations of plant systems.

■ *For more information, contact Russ Pflasterer, (415) 855-2541.*

Lincoln Electric, School District Find Ground-Coupled Heat Pumps a Winner

Lincoln Electric System (LES), a municipal utility in Nebraska, encourages customer use of heat pumps as part of its demand-side management efforts. In 1992, when city voters approved the construction of four new elementary schools, LES and the Lincoln School District saw an opportunity to evaluate potential heating, ventilating, and air conditioning (HVAC) technologies for the schools to determine which would perform most efficiently at the lowest energy cost. The school district and LES together identified candidate technologies, including gas-electric combinations, water-loop heat pumps, and ground-coupled heat pumps.

Using energy cost and technical data from LES and building occupancy and use information from the school district, the project's architect-engineering firm developed life-cycle cost projections for the candidate systems. The analysis identified ground-coupled heat pumps as the lowest-cost option, with water-loop heat pumps second.

To confirm the modeling results, LES contacted EPRI in search of a suitable alternative model. In short order, COMTECH—EPRI software for analyzing HVAC options for commercial buildings—was supplied, and it produced an identical ranking of the candidate systems. The school district remained reluctant, however, to commit to the nontraditional technology of ground-coupled heat pumps. To familiarize the design team with the technology, LES held a one-day symposium that featured presentations by EPRI staff, heat pump manufacturers, and other experts. Further along in the project planning, at the utility's request, EPRI facilitated a design review by an independent consultant. The review resulted in a 33% reduction in the loop field size, representing estimated savings of $240,000 in construction costs, and solidified the school district's confidence in the technology.

Construction began in the summer of 1994, and the schools opened in September 1995. LES and the school district worked together to add instrumentation and sensing equipment to each school's loop field and building energy management system in order to monitor and optimize their operation. Detailed performance monitoring of the heat pump systems indicated their projected energy cost savings for the school district in 1996 to be $128,000. And the projected annual peak load is about half that of the HVAC system originally proposed, resulting in avoided-cost savings of $324,000 for LES. To date, the systems have exceeded everyone's expectations, providing not only higher energy efficiency and lower energy costs but also greater comfort than school staff members say they've ever had.

Heat pump system piping ready for installation

EPRI's COMTECH software is available from the Electric Power Software Center, (800) 763-3772.

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

Global Climate Change

Potential Ecological and Economic Impacts of Climate Change

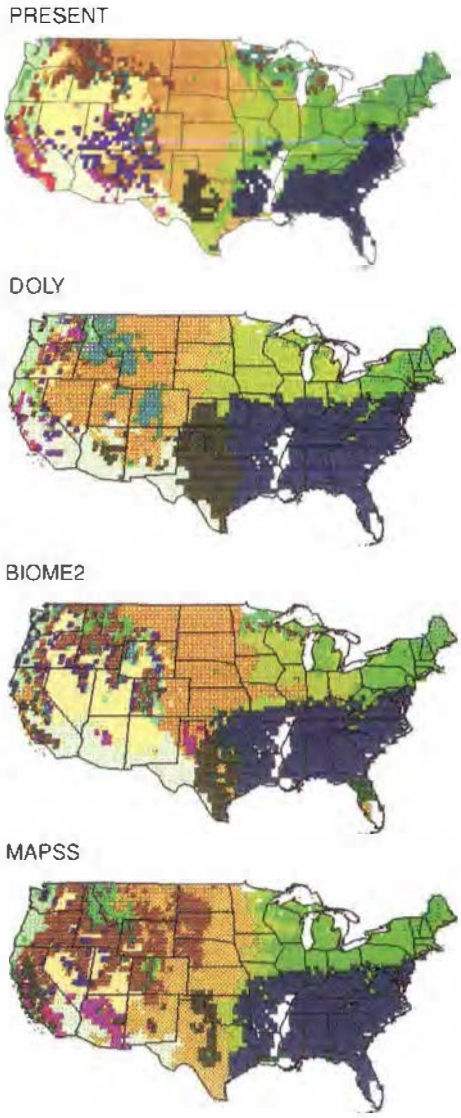
by Tom Wilson and Lou Pitelka, Environment Group

Predictions that rising atmospheric concentrations of greenhouse gases—particularly carbon dioxide resulting from fossil fuel combustion—will cause global climate change are compelling policymakers and others to consider approaches for limiting greenhouse gas emissions. The intent is to mitigate undesirable ecological, human, and economic effects of changes in climate parameters. However, the scientific basis for both climate change predictions and hypothesized impacts is highly uncertain.

This uncertainty makes it extremely difficult to determine the benefits, in terms of reductions in negative impacts, that climate change management proposals would achieve. The costs to the United States of complying with any of a number of mitigation proposals currently under consideration are on the order of several hundred billion dollars annually. To facilitate cost-benefit analysis during policy decision making, EPRI's global climate change research program is assessing possible impacts on both nonmarket systems and market-based systems. Nonmarket concerns include ecosystem function and structure, biodiversity, and human health. Potentially vulnerable market sectors include agriculture, forestry, coastal resources, water resources, commercial fisheries, and recreation.

Focusing on the plausible ranges of climate change predicted by state-of-the-art general circulation models (GCMs), EPRI research seeks to determine how nonmarket and market-based systems might be affected in the United States and in other countries, to assess the approximate extent and magnitude of impacts, and to quantify the value of these impacts. The EPRI work is designed to build on research funded by other organizations and to fill critical gaps in understanding. The overall objective is to provide policymakers with information required to estimate what proposed mitigation measures will achieve in terms of reducing undesirable impacts.

Figure 1 In the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP), researchers used three biogeography models—DOLY, BIOME2, and MAPSS—to simulate the effects of climate change on the distribution of major vegetation communities. Shown here are the modeled vegetation distributions for the present climate and for a doubled-CO_2 climate scenario based on a general circulation model experiment conducted by Oregon State University. According to these simulations, climate change could significantly alter vegetation distribution; for example, zones for major vegetation types could shift northward, especially in the eastern United States (as indicated in blue for warm temperate mixed/evergreen forests). For more information on the VEMAP research, see EPRI technical brief TB-106224.



ABSTRACT *Calls for curbing greenhouse gas emissions are driven by concerns that climate change could lead to undesirable impacts on ecological, human, and economic systems. EPRI is devoting significant effort to understanding and quantifying the value of potential effects. Work to date indicates that ecological impacts are highly uncertain but that aggregate damages to the U.S. economy are likely to be substantially lower than previously estimated, with some sectors realizing net benefits. These results will be important input for future integrated assessments that will provide policymakers with comprehensive cost-benefit analyses of climate change management proposals.*

Ecological effects research

Research to improve understanding of possible ecological effects is particularly important both because of the great uncertainty concerning their nature and magnitude and because of the likelihood that such effects would be considered undesirable. Major characteristics of an ecological system that could be affected by climate change include the geographic distribution of dominant plant communities, basic ecosystem processes and their feedbacks to the climate system, the productivity of economically and aesthetically important species, and biodiversity.

Some of the most advanced simulations to date of possible effects on natural terrestrial ecosystems have been performed under the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP), an international collaboration cofunded by EPRI, the National Aeronautics and Space Administration, and the U.S. Forest Service, with additional support for database development from the National Science Foundation. For scenarios predicted by state-of-the-art GCMs for an equilibrium climate characterized by an atmospheric concentration of CO_2 double preindustrial levels, VEMAP is comparing and combining the predicted ecological responses from two types of models: biogeography models, which simulate such shifts in ecosystem structure as vegetation distribution, and biogeochemistry models, which predict changes in such ecosystem functions as net primary productivity (NPP) and carbon and nutrient cycling. In VEMAP's linked simulations, vegetation redistributions predicted by biogeography models are used to drive biogeochemistry models. As a result, these simulations are more realistic than earlier studies, which did not incorporate the effects of structural changes when estimating impacts on functional attributes.

VEMAP results indicate that important ecosystem properties, including vegetation distribution, NPP, and total carbon storage, could be sensitive to climate change. For example, shifts, expansions, and contractions of forests, grasslands, and other plant ecosystems are predicted; in particular, zones of major vegetation types shift northward, especially in the eastern United States (Figure 1). Linked simulations project NPP increases of up to 40% (Figure 2) and yield a range of estimates on total carbon storage (from a 30% gain to a 39% loss); the results vary widely in magnitude and by region, depending on the combination of models used. This substantial uncertainty reflects the limitations of existing GCMs and ecological models. Clearly, improved model accuracy is needed, as well as the ability to simulate transient dynamics rather than steady-state responses to some equilibrium future climate, such as that associated with doubled CO_2. The course of change—that is, the actual rates and patterns of ecological responses through time—may be more important, from both scientific and policymaking perspectives, than the features of some future equilibrium state.

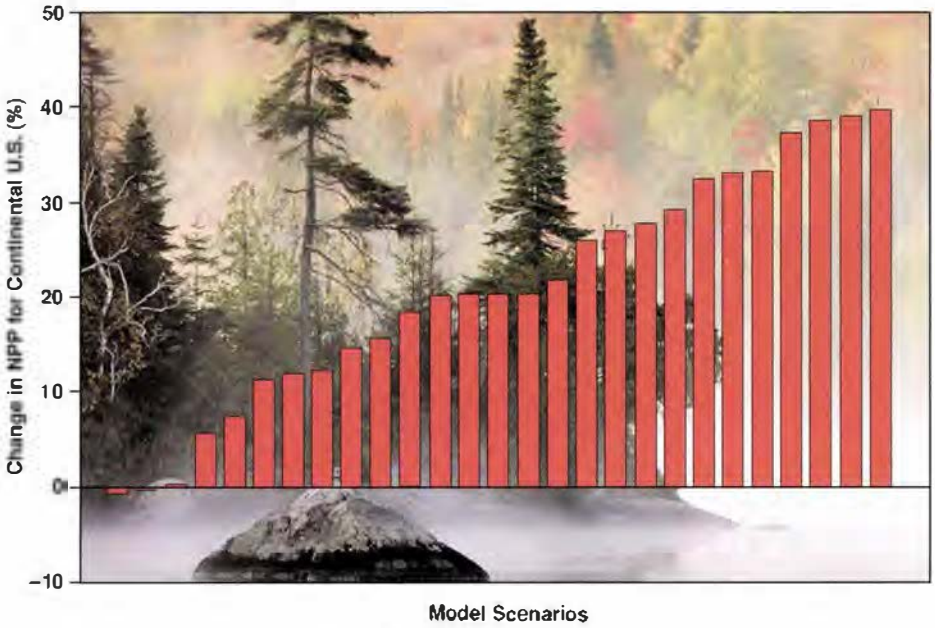


Figure 2 In VEMAP, 27 scenarios (all the possible combinations of scenarios from 3 general circulation models, 3 biogeography models, and 3 biogeochemistry models) were evaluated to better understand the potential effects of a doubled-CO_2 atmosphere. Shown here are the scenarios' estimates of changes in net primary productivity, a measure of ecosystem growth. Although the change in NPP varies significantly across the 27 scenarios, it is almost always positive—a critical reason that the results of EPRI's timber market analysis are more positive than those of earlier timber analyses.

Although most ecological effects research has focused on vegetation, society is likely to be at least as concerned about wildlife. In preliminary EPRI modeling research, potential direct and indirect impacts have been evaluated for elk and ground squirrels in the western United States and for deer and chipmunks in the eastern United States. These species were chosen because of their abundance, their aesthetic appeal, and the availability of biological data on them.

The results of this preliminary research suggest that climate change alone would have little or no effect on species distribution, since the animals' physiological tolerance to increased heat load would allow them to survive in current habitats. An analysis of indirect impacts indicates that since habitat and vegetation are inherently linked, the vegetation shifts predicted by VEMAP could alter species range and abundance, with populations increasing when suitable habitat expands and declining when suitable habitat is lost. More-realistic modeling of climate change effects on wildlife requires a finer spatial scale, however, because natural populations vary in habitat type within much smaller areas than the 10-km-square grid cell used in VEMAP.

Economic effects studies

Before the EPRI work began in 1993, most estimates of possible economic impacts were derived from late-1980s studies of individual sectors funded by the U.S. Environmental Protection Agency. These studies found that possible impacts in a number of sectors are potentially large, highly uncertain, and likely to be detrimental in

some areas and beneficial in others. Prominent published aggregate damage estimates, based largely on the EPA work, range from $55 billion to $111 billion (in 1990 dollars) for the U.S. economy in 2060 (Table 1).

The initial EPRI research examined the methodologies underlying these estimates in order to facilitate comparative evaluation and provide guidance for improved impact assessment. The analyses indicated that much of the scatter in the aggregate estimates could be explained by differences in the authors' assumptions about the amount of climate change and sea-level rise, rates of return on investment, and changes in population and income. When linearly adjusted to correct for differences, aggregate damage estimates for a 2.5°C temperature increase and a 50-cm rise in sea level span a much smaller range, from $42 billion to $53 billion (in 1990 dollars).

Table 1
Published Estimates of U.S. Climate Change Impacts in the Year 2060 (in billions of 1990 dollars)

	Nordhaus (1991)	Cline (1992)	Titus (1992)	Tol* (1995)	Fankhauser (1995)
Market impacts					
Agriculture	−1.1	−17.5	−1.2	−10.9	−8.1
Timber	—	−3.3	−43.6	—	−0.7
Water resources	—	−7.0	−39.8	—	−14.9
Energy	−0.5	−9.9	−5.6	—	−7.5
Sea level, including coastal structures	−11.6	−7.0	−5.7	−9.3	−8.6
Total (market)	−13.2	−44.7	−95.9	−20.2	−39.8
Nonmarket impacts					
Human life	—	−5.8	−9.4	−41.1	−10.9
Human migration	—	−0.5	—	−1.1	−0.5
Extreme weather	—	−0.8	—	−0.3	−0.2
Recreation	—	−1.7	—	—	—
Species loss	—	−4.0	—	−5.5	−8.1
Air pollution	—	−3.5	−5.2	—	−7.0
Other	—	−0.1	—	−13.1	—
Total (nonmarket)	−42.0†	−16.4	−14.6	−61.1	−26.7
Total (both)	−55.2	−61.1	−110.5	−81.3	−66.5
% of 1990 GNP	−1.0%	−1.1%	−2.0%	−1.3%	−1.2%

Note: Adapted from J. Smith, "Review of Climate Change Impacts," *Climatic Change* (forthcoming issue). Estimates have been adjusted for inflation.

*Estimates include Canada.

†Nordhaus calculated market impacts and then suggested that total impacts could be 1% of U.S. gross national product, implying this value for nonmarket impacts.

EPRI also identified several limitations in the individual-sector studies. Most important, the studies did not fully account for the adaptive nature of market systems. In addition, they were based on climate conditions that lie toward the worst-case end of the range currently being considered by the Intergovernmental Panel on Climate Change (IPCC). A more subtle weakness is that the estimates were based on a 1990 economy operating in 2060. Although difficult, it is important to understand how potential changes in the economy over time might affect climate sensitivity. Finally, each sector study provided impact estimates for only a small set of climate scenarios, making the results difficult to interpret for alternative scenarios.

To better understand potential economic effects, EPRI is conducting a second generation of impact assessments. In many cases, these studies employ methodologies similar to those of the initial EPA work, as well as the same researchers. However, the new studies explicitly incorporate the adaptation intrinsic to human society. Timber and coastal structures damage models are dynamic rather than static in order to investigate the sensitivity of vast timber and building stocks to the rate of climate change. And the new studies use common economic and growth assumptions—along with a wide range of plausible scenarios to measure climate sensitivity, including temperature increases of 1.5, 2.5, and 5°C and precipitation increases of 0, 7, and 15%.

For a central climate scenario (a 2.5°C temperature increase and a 7% precipitation increase), Table 2 presents results for several sectors: agriculture, timber, water resources (both market effects related to changes in water prices and supply and nonmarket effects related to changes in water quality), energy, coastal structures, and recreation. These new estimates are more moderate than previously published estimates primarily because they are based on lower IPCC climate change projections, include adaptation, reflect more-comprehensive sector analysis, and, in the case of the timber market analysis, rely on ecological models.

EPRI's work on the agricultural impacts of climate change illustrates how market-based adaptation could significantly reduce negative effects. In the EPA's 1989 assessment, in which no crop migration or farm-level adaptation was assumed, Texas A&M's Agricultural Simulation Model (ASM) projected an annual loss of $7.5 billion in the value of U.S. agricultural production for a fairly central climate scenario based on a GCM. In the EPRI work, the ASM was for the first time allowed to simulate an expected shift by southern farmers toward high-value, heat-tolerant crops like fruits and vegetables if the grain belt migrated northward. Also considered were possible changes in forage and livestock production and potential technology advances, such as breeding for increased heat tolerance. For a 1990 economy and the same GCM climate scenario used in the EPA study (which differs from the uniform-change scenario shown in Table 2), the "adaptable" model predicted that the annual value of U.S. agricultural production would *increase* by nearly $15 billion.

To assess impacts on coastal structures, the EPRI studies incorporated up-to-date estimates for possible sea-level rise (33 or 66 cm by 2100 instead of the 1-m rise used in previous studies). Also, rather than assuming that all coastal areas would be pro-

tected immediately, they allowed for dynamic, market-based decisions about protecting property when it is threatened. For example, cost-effective protection strategies can be developed by dividing vulnerable areas into regions where immediate protection is required, regions where protective dikes could be built just before inundation, regions where protection costs outweigh property losses, and so on. EPRI's approach resulted in a central-case estimate of about $100 million for losses directly attributable to the protection or abandonment of U.S. coastal structures, an order of magnitude lower than earlier estimates.

The EPRI studies of potential forestry impacts used a significantly different method from that of previous studies, which were handicapped by limited modeling of links between climate change and forest response. The EPRI approach capitalized on VEMAP, integrating predictions from its ecological models with GCM scenarios and economic models to identify the steady-state and dynamic responses of forest resources and timber markets. The results indicate that U.S. timber markets will benefit from climate change, largely because land suitable for commercial forests is projected to increase—particularly for high-value, short-rotation forests in the Southeast. Initial ecological impacts, such as productivity decreases or dieback increases, are expected to be offset by market adaptation, including efficient use of existing stock, salvage logging of dieback stock, and timely replanting and forest expansion. For the climate scenarios and ecosystem models used in the EPRI work, the U.S. timber market's value is projected to *increase* as a result of warming; in contrast, studies in the literature estimate timber losses.

Analyses of the other sectors in Table 2 provide similar insights. The detailed results of these studies are scheduled to be published later this year by Cambridge University Press.

Ongoing and future assessments

Current and planned work focuses on extending existing studies and initiating studies of potential human health effects.

Under VEMAP, transient dynamics are being incorporated into existing models to facilitate the prediction of real-time responses of natural U.S. ecosystems to changing climate. Modeling of transient dynamics will also begin to address how climate change might affect the complex feedbacks between the interrelated, time-dependent processes that control ecosystem responses. Plans are to eventually extend the modeling approach used in VEMAP to evaluate possible effects on global ecosystems.

As for animals and biodiversity, lessons learned from the initial studies will guide future research efforts. In particular, EPRI work will simulate, at small scales of spatial resolution, the effects of changing ecosystem boundaries and characteristics on economically and aesthetically important wildlife, such as sport fish, game species, and endangered species.

In a combined ecology-market impact study, the effects of elevated CO_2 on ponderosa pines are being evaluated to determine whether forest growth and carbon storage rates will increase as atmospheric CO_2 levels rise. The results will be used to improve the modeling of forest productivity and ecosystem responses and the economic assessment of potential forestry impacts. This project will also help clarify feedbacks between the terrestrial biosphere and the atmosphere and thus will improve understanding of the global carbon cycle.

The focus of EPRI work on market impact assessments is shifting to other countries. Although potential effects from gradual climate change appear relatively small for U.S. market sectors, this may not hold true in areas where market conditions and the

Table 2
Estimated U.S. Impacts of Doubled-CO_2 Climate in 2060
(in billions of 1990 dollars)

Sector	EPRI Estimates (+2.5°C, +7% precipitation) 2060 Economy	EPRI Estimates (+2.5°C, +7% precipitation) 1990 Economy	Previous Estimates: 1990 Economy	EPRI Methodological Improvements
Market				
Agriculture	−41.4	+11.3	−1 to −18	Includes additional crops and adaptation opportunities
Timber	+3.4	+3.4	−1 to −44	Dynamic climate, ecological, and timber modeling
Water resources	−3.7	−3.7	−7 to −40	Integrated hydrologic and economic models
Energy	−4.1	−2.5	−1 to −10	Includes all space-conditioning fuels
Coastal structures*	−0.1	−0.1	−1.2 to −6	Dynamic analysis of representative sites
Commercial fishing	−0.4 to +0.4	−0.4 to +0.4	—	First estimates developed for this sector
Total	+36.9	+8.4	−13 to −96	
% of GNP	+0.2% (2060)	+0.2% (1990)	−0.3% to −0.9% (1990)	
Nonmarket				
Water quality†	−5.7	−5.7	−13.2	Basin-based regional estimates
Recreation	+3.5	+4.2	−1.7	Covers a broad range of summer and winter activities and includes empirical evidence

Note: All estimates assume an effective doubling of atmospheric CO_2. Previous estimates are based on sources in Table 1.

*The EPRI estimates assume a 33-cm rise in sea level.

†The EPRI nonmarket estimates cover nonconsumptive water resource components except for hydroelectric production, which is included in the market sector impact estimates.

ability to respond are different. For example, it has been suggested that developing countries lacking wealth and market flexibility may be more susceptible to negative effects. Methodologies used to evaluate impacts in the United States will be applied to agriculture, coastal property, water resource, and energy sectors elsewhere; an initial project, cofunded by the World Bank, is assessing effects on agriculture in India.

In another area of effort, EPRI has initiated research into possible climate-related human health effects. Hypothesized human health impacts are both direct (e.g., heat stress or injury from natural disasters) and indirect (e.g., malnutrition or famine due to agricultural changes, respiratory problems caused by air pollution, or increased incidence of vector-borne diseases like malaria). Although health effects research is in its infancy, one IPCC source estimates that such impacts, particularly heat stress, could account for over 50% of the total damages from climate change. The focus of EPRI's program is to understand the basic issues in predicting effects, to communicate clearly what is known and not known, and to initiate modeling activities to improve existing estimates where appropriate.

Integrated assessment

As results become available from various market and nonmarket effects studies, they are incorporated into integrated-assessment frameworks being developed in other EPRI work. These frameworks provide several computerized, science-based decision support systems that synthesize diverse information about the relationship between human activities and greenhouse gas emissions, the effects of these emissions on climate, and the impacts of climate change on ecological and economic systems.

The frameworks will allow direct, systematic comparison of the costs and benefits of climate change management proposals, providing critical information for the overall decision-making process. They will also facilitate appraisal of the value of alternative R&D strategies, giving EPRI and other organizations a tool for prioritizing resource allocation to address key uncertainties or areas of concern.

New Technical Reports

Requests for copies of reports should be directed to the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, California 94523; (510) 934-4212. Two-page summaries of the reports announced here are available, free of charge, by fax. To receive a summary, call EPRI's Fax on Demand service (800-239-4655) from a touch-tone phone and follow the recorded instructions, using the fax identification number given in the report listing.

CUSTOMER SYSTEMS

Motor and Drive Technology and Applications in the Textile Industry
TR-102505 Final Report (WO3887-15)
Contractor: North Carolina Alternative Energy Corp.
EPRI Project Manager: B. Banerjee
Fax ID: 7545

Broadcast and Multicast for Customer Communications and Distribution Automation
TR-106354 Final Report (WO3567-1, WO3674)
EPRI Project Managers: L. Carmichael, W. Blair
Fax ID: 25754

Multifamily Housing, Vol. 1: A Resource and Marketing Guide for Electric Utilities
TR-106442-V1 Final Report (WO3512-14)
Contractor: A. T. Kearney
EPRI Project Manager: S. Kondepudi
Fax ID: 39873

Energy-Efficient Ducts: A Practical Overview
TR-106443 Final Report (WO3512-14)
Contractor: Saturn Resource Management
EPRI Project Manager: S. Kondepudi
Fax ID: 40491

The Emerging Energy Services Market: A Business Planning Guide
TR-106527 Final Report (WO2343-21)
Contractor: Barakat & Chamberlin, Inc.
EPRI Project Manager: P. Sioshansi
Fax ID: 26031

Effects of Refrigerant Charge, Duct Leakage, and Evaporator Air Flow on the High-Temperature Performance of Air Conditioners and Heat Pumps
TR-106542 Final Report (WO3884)
Contractor: Texas A&M University System
EPRI Project Manager: S. Kondepudi
Fax ID: 26062

The Effect of Hardware Configuration on the Performance of Residential Air Conditioning Systems at High Outdoor Ambient Temperatures
TR-106543 Final Report (WO3884)
Contractor: Texas A&M University System
EPRI Project Manager: S. Kondepudi
Fax ID: 26063

The Effects of Hydrophobic Surface Treatments on Dropwise Condensation and Freezing of Water
TR-106544 Final Report (WO8034)
Contractor: Texas A&M University System
EPRI Project Manager: S. Kondepudi
Fax ID: 26061

Scoping Study: Surface Mount Technology and Applications in Power Electronics and Control Systems
TR-106654 Final Report (WO3088-2)
Contractor: Auburn Technology, Inc.
EPRI Project Manager: B. Banerjee
Fax ID: 26225

Potential for the Increased Efficiency in Motors in the Chemical and Processing Industries
TR-106655 Final Report (WO3552-1)
Contractor: University of New Orleans
EPRI Project Manager: B. Banerjee
Fax ID: 26227

Ventilation Best Practices Guide
TR-106662 Final Report (WO3280-48)
Contractors: Dorgan Associates, Inc., EPRI HVAC&R Center/University of Wisconsin, Madison
EPRI Project Managers: J. Kesselring, M. Khattar
Fax ID: 40652

Minimum Energy Ventilation for Fast-Food Restaurant Kitchens
TR-106671 Final Report (WO3563)
Contractors: Architectural Energy Corp.; International Facility Management Association
EPRI Project Manager: W. Krill
Fax ID: 26294

Infiltration and Ventilation Measurements on Three Electrically Heated Multifamily Buildings
TR-106675 Final Report (WO2417-21)
Contractor: Ecotope, Inc.
EPRI Project Manager: J. Kesselring
Fax ID: 40427

Unitary Thermal Energy Storage System Performance
TR-106729 Final Report (WO3906-1)
Contractor: Powell Energy Products, Inc.
EPRI Project Manager: M. Khattar
Fax ID: 26382

Technology Trends in Portable Electric Power Tools
TR-106732 Final Report (WO3087-10)
Contractor: Black & Decker Corp.
EPRI Project Manager: B. Banerjee
Fax ID: 26387

Performance Measurement in Utilities: A Framework for Creating Effective Management Systems
TR-106860 Final Report (WO3269-34)
Contractor: Hagler Bailly Consulting, Inc.
EPRI Project Manager: R. Gillman
Fax ID: 26594

Performance Measurement: Measuring Effectiveness of Utility Sales Forces
TR-106861 Final Report (WO3269-4TS2426)
Contractor: Coopers & Lybrand Consulting/Palmer Bellevue
EPRI Project Manager: R. Gillman
Fax ID: 26596

New Product Introductions: Case Histories From Other Industries
TR-106901 Final Report (WO4853-3)
Contractor: Putnam, Hayes & Bartlett, Inc.
EPRI Project Manager: T. Henneberger
FaxID: 26652

Performance Measurement: Establishing Energy Impacts of Commercial Retrofit Programs (A Pacific Northwest Study)
TR-106923 Final Report (WO3539-1)
Contractor: XENERGY Inc.
EPRI Project Manager: R. Gillman
FaxID: 39876

Performance Measurement: Establishing Energy Impacts of Commercial New Construction Programs (A Pacific Northwest Study)
TR-106924 Final Report (WO3539-1)
Contractors: XENERGY Inc.; Regional Economic Research, Inc.; Architectural Engineering Corp
EPRI Project Manager: R. Gillman
Fax ID: 39877

State and Federal Vertical Borehole Grouting Regulations
TR-107043 Interim Report (WO3881-1)
Contractor: University of Idaho
EPRI Project Manager: C. Hiller
Fax ID: 40929

ENVIRONMENT

Field Demonstration of Thermal Desorption of Manufactured Gas Plant Soils
TR-105927 Final Report (WO9015-20)
Contractor: Barr Engineering Co.
EPRI Project Managers: L. Goldstein, I. Murarka
Fax ID: 24990

Melatonin Levels in Continuous Magnetic Fields
TR-106178 Final Report (WO9095-1)
Contractor: Midwest Research Institute
EPRI Project Manager: R. Kavet
Fax ID: 25432

Mixtures of a Coal Combustion By-Product and Composted Yard Wastes for Use as Soil Substitutes and Amendments
TR-106682 Final Report (WO3270-6)
Contractor: Ohio State University Research Foundation
EPRI Project Manager: I. Murarka
FaxID: 26308

Protocol for Estimating Historic Atmospheric Mercury Deposition
TR-106768 Final Report (WO3297)
EPRI Project Manager: D. Porcella
Fax ID: 26443

Dallas–Fort Worth Winter Haze Project, Vols. 1–3
TR-106775-V1-V3 Final Report (WO9019)
Contractor: ENSR Consulting and Engineering
EPRI Project Manager: P. Mueller
Fax ID: 40409

Design of a Framework for the Development of a Comprehensive Modeling System for Air Pollution
TR-106852 Final Report (WO4311-2)
EPRI Project Manager: A. Hansen
Fax ID: 40411

Human Exposure to Arsenic In Drinking Water
TR-107027 Final Report (WO3370-11)
Contractors: Universidad Nacional Autónoma de México; EcoAnalysis, Inc.
EPRI Project Manager: J. Yager
FaxID: 40046

EPRI EMF Exposure Database: EMDEX Occupational Study Data Set
TR-107058 Final Report (WO2966-13)
Contractor: T. Dan Bracken, Inc.
EPRI Project Manager: R. Takemoto-Hambleton
Fax ID: 40148

EPRI EMF Exposure Database: Telephone Line Workers Data Set
TR-107059 Final Report (WO2966-13)
Contractor: T. Dan Bracken, Inc.
EPRI Project Manager: R. Takemoto-Hambleton
Fax ID: 40150

EPRI EMF Exposure Database: SCE Utility Workers Data Set
TR-107060 Final Report (WO2966-13)
Contractor: T. Dan Bracken, Inc.
EPRI Project Manager: R. Takemoto-Hambleton
Fax ID: 40152

EPRI EMF Exposure Database: Electrical Workers Data Set
TR-107061 Final Report (WO2966-13)
Contractor: T. Dan Bracken, Inc.
EPRI Project Manager: R. Takemoto-Hambleton
Fax ID: 40154

GENERATION

Corrosion Fatigue Boiler Tube Failures in Waterwalls and Economizers, Vol. 5: Application of Guidelines at Hazelwood Power Station
TR-100455-V5 Final Report (WO1890-5)
Contractors: HRL Technology Pty. Ltd.; Ontario Hydro
EPRI Project Manager: B. Dooley
Fax ID: 23239

State-of-the-Art Weld Repair Technology for High-Temperature and -Pressure Parts, Vol. 3: Turbine Casing, Piping, and Header Utility Survey, Vendor Survey, and Bibliography
TR-103592-V3 Final Report (WO3484-1)
Contractor: EPRI Repair and Replacement Applications Center
EPRI Project Manager: R. Viswanathan
Fax ID: 20591

Monitoring of Plant Electrical Auxiliary Systems, Part 3: Extension and Diagnostic Rules
TR-104152-V2 Final Report (WO2626)
Contractors: Consolidated Edison Co. of New York, Inc.; Empire State Electric Energy Research Corp.
EPRI Project Manager: J. Stein
Fax ID: 40004

Condensate Polishing Guidelines
TR-104422 Final Report (WO2712-10, WO2977-WO9003)
Contractor: Black & Veatch
EPRI Project Manager: B. Dooley
Fax ID: 22095

Liner-Waste Compatibility Studies for Coal-Fired Power Plants
TR-104947 Final Report (WO1457-1)
Contractor: Henry E. Haxo, Jr.
EPRI Project Managers: M. McLearn, D. Golden
FaxID: 23455

Environmental and Physical Properties of Autoclaved Cellular Concrete
TR-105821-V1-V3 Final Report (WO9040-1)
Contractor: University of Pittsburgh
EPRI Project Manager: D. Golden
Fax ID: 24809

Gas Turbine Vibration Monitoring and Analysis System, Vols. 1 and 2
TR-106008-V1-V2 Final Report (WO3535)
Contractor: Southwest Research Institute
EPRI Project Manager: G. Quentin
Fax ID: 25129

Pollution Prevention Procedure and Case Studies for Utility Waste
TR-106176 Final Report (WO3006-6)
Contractor: Radian Corp.
EPRI Project Manager: M. McLearn
Fax ID: 25429

Arizona Public Service Solar Test and Research (STAR) Center, Vols. 1 and 2
TR-106403-V1-V2 Final Report (WO1607-12)
Contractor: Arizona Public Service Co.
EPRI Project Manager: F. Goodman
Fax ID: 25866

Southern California Edison's Solar Neighborhood Program: Phase I Report
TR-106405 Final Report (WO3766)
Contractor: Southern California Edison Co.
EPRI Project Manager: F. Goodman
Fax ID: 25864

Utility Integration of Photovoltaic Systems
TR-106406 Final Report (WO3179-1)
Contractor: Elektrotek Concepts, Inc.
EPRI Project Manager: F. Goodman
Fax ID: 25863

Development of Manufacturing Capability for High-Concentration, High-Efficiency Silicon Solar Cells
TR-106407 Final Report (WO2703)
Contractor: SunPower Corp.
EPRI Project Manager: F. Goodman
Fax ID: 25862

Photovoltaic Systems at TU Electric Energy Park
TR-106408 Final Report (WO3779)
Contractor: TU Electric
EPRI Project Manager: F. Goodman
Fax ID: 25861

Photovoltaic Systems Operations at TU Electric Energy Park
TR-106409 Interim Report (WO3779-2)
Contractor: TU Electric
EPRI Project Manager: F. Goodman
Fax ID: 25860

High-Concentration Photovoltaic Cell Research
TR-106410 Final Report (WO2703)
Contractor: SunPower Corp.
EPRI Project Manager: F. Goodman
Fax ID: 25859

Photovoltaic System Performance Assessment for 1991
TR-106411 Final Report (WO4058)
Contractor: New Mexico State University
EPRI Project Manager: F. Goodman
Fax ID: 25858

Photovoltaic Balance-of-System Designs and Costs at PVUSA
TR-106412 Final Report (WO3490)
Contractors: Bechtel Corp.; Pacific Gas and Electric Co.; PVUSA Project Team
EPRI Project Manager: F. Goodman
Fax ID: 25857

1994 PVUSA Progress Report
TR-106413 Final Report (WO3490)
Contractor: PVUSA Project Team
EPRI Project Manager: F. Goodman
Fax ID: 25856

Dendritic Web Photovoltaic Program
TR-106414 Final Report (WO2611-1)
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: F. Goodman
Fax ID: 25855

Temperature Sensor Evaluation
TR-106453 Final Report (WO3925)
Contractor: Pacific Gas and Electric Co.
EPRI Project Manager: J. Weiss
Fax ID: 106453

Guidelines for Implementing the Plant Monitoring Workstation
TR-106495 Final Report (WO3499-1)
Contractors: Centerior Energy Corp.; Entor Corp.
EPRI Project Managers: R. Pflasterer, M. Perakis
Fax ID: 25984

A Study of Toxic Emissions From a Gasification–Combined-Cycle (GCC) Power Plant
TR-106619 Final Report (WO3177-9)
Contractor: Radian Corp.
EPRI Project Managers: P. Chu, M. Epstein
Fax ID: 26174

State of the Art of Fuel Cell Technologies for Distributed Power: Technical and Strategic Assessment of Products, Markets, and Retail Competitiveness
TR-106620 Final Report (WO4297-1)
EPRI Project Manager: D. Rastler
Fax ID: 26181

Solid-Oxide Fuel Cell: 20-kW Module Engineering and Cost Study
TR-106644 Final Report (WO3608-2)
Contractor: Technology Management, Inc.
EPRI Project Manager: D. Rastler
Fax ID: 26213

Commercial-Sector Solid-Oxide Fuel Cell Business Assessment
TR-106645 Interim Report (WO8502)
Contractor: Resource Dynamics Corp.
EPRI Project Manager: D. Rastler
Fax ID: 26214

Assessing DSM and Distributed Generation Opportunities in the Service Areas of the Salt River Project
TR-106646 Final Report (WO3897)
Contractor: Salt River Project Study Team
EPRI Project Manager: D. Rastler
Fax ID: 26215

Methyl Mercury in Coal Combustion Flue Gas
TR-106685 Final Report (WO3471-6)
Contractor: Frontier Geosciences, Inc.
EPRI Project Manager: B. Nott
Fax ID: 26312

Properties of Modified 9Cr-1Mo Cast Steel
TR-106856 Final Report (WO4051-1)
Contractor: ABB-CE
EPRI Project Manager: W. Bakker
Fax ID: 26588

Proceedings: 12th International Symposium on Coal Combustion By-Product Management and Use, Vols. 1 and 2
TR-107055-V1-V2 Proceedings (WO3176)
Contractor: American Coal Ash Association
EPRI Project Manager: D. Golden
Fax ID: 40142

Power Plant Wastewater Treatment Technology Review Report
TR-107081 Final Report (WO2114)
Contractors: Lockwood Greene Engineers; Water Systems Specialists, Inc.
EPRI Project Manager: B. Nott
Fax ID: 40191

Generic Specification for Plant Information Networks
TR-107103 Final Report (WO3402)
Contractor: Entor Corp.
EPRI Project Manager: G. Lamb
Fax ID: 40245

NUCLEAR POWER

Recommendations for an Effective Flow-Accelerated Corrosion Program
NSAC-202L-R1 Final Report (WO4117-1)
Contractor: Altos Engineering
EPRI Project Manager: B. Chexal
Fax ID: 41155

PWR Secondary Water Chemistry Guidelines—Revision 4
TR-102134-R4 Final Report (WO2493, WOS520)
EPRI Project Manager: C. Wood
Fax ID: 40257

Stress Corrosion Cracking of Reactor Pressure Vessel Steels
TR-103160 Final Report (WOC106-6)
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: R. Pathania
Fax ID: 19843

Plant-Wide Integrated Environment Distributed on Workstations (Plant Window) System Functional Requirements
TR-104756 Final Report (WO4500-1)
Contractors: Oak Ridge National Laboratory; MPR Associates, Inc.
EPRI Project Manager: J. Naser
Fax ID: 23121

Proceedings: Specialist Meeting on Environmental Degradation of Alloy 600
TR-104898 Proceedings (WOS406)
EPRI Project Manager: A. McIlree
Fax ID: 23367

Fire Ignition Frequency Model at Shutdown for U.S. Nuclear Power Plants
TR-105929 Final Report (WO3114-29)
Contractor: SAIC
EPRI Project Manager: R. Kassawara
Fax ID: 24994

Evaluation of Zinc Addition to Primary Coolant of Farley-2 PWR
TR-106358-V1 Final Report (WO4023-1)
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: R. Pathania
Fax ID: 25762

Evaluation of Zinc Addition to Primary Coolant of PWRs: Fuel Cladding Corrosion
TR-106358-V2 Final Report (WO4023-1)
EPRI Project Manager: R. Pathania
Fax ID: 25764

Guideline on Evaluation and Acceptance of Commercial-Grade Digital Equipment for Nuclear Safety Applications
TR-106439 Final Report (WO4488-1)
Contractor: MPR Associates, Inc.
EPRI Project Manager: R. Torok
Fax ID: 25910

User's Guide to PREP4: Power Reactor Embrittlement Program, Version 1.0
TR-106726 Computer Manual (WO2975)
Contractor: ATI Consulting
EPRI Project Manager: S. Rosinski
Fax ID: 40410

Interim On-Site Storage of Low Level Waste: Guidelines for Extended Storage, Revision 1
TR-106925 Final Report (WO3800)
EPRI Project Manager: C. Hornibrook
Fax ID: 39880

1995 Revisions to DOT and NRC Transport Regulations and Their Impact on Nuclear Power Plants
TR-106926 Final Report (WO2414)
Contractors: Gretta Consulting, Inc.; ERS Corp.
EPRI Project Manager: C. Hornibrook
Fax ID: 39882

WASTECOST Handbook
TR-106927 Final Report (WO2414)
Contractor: ERS Corp.
EPRI Project Manager: C. Hornibrook
Fax ID: 39884

Proceedings: 1996 ASME/EPRI Radwaste Workshop
TR-106928 Proceedings (WO2414)
Contractor: Paul Williams & Associates
EPRI Project Manager: C. Hornibrook
Fax ID: 39886

Proceedings: 1996 EPRI International Low Level Waste Conference
TR-106929 Proceedings (WO2414)
Contractor: Paul Williams & Associates
EPRI Project Manager: C. Hornibrook
Fax ID: 39888

Technical Basis for ASME Code Case N-557: In-Place Dry Annealing of a PWR Nuclear Reactor Vessel
TR-106967 Final Report (WO4075-4)
Contractor: ATI Consulting
EPRI Project Manager: S. Rosinski
Fax ID: 39945

Full-System Decontamination of the Indian Point 2 PWR
TR-107039 Final Report (WO3396-1)
Contractor: PN Services
EPRI Project Manager: C. Wood
Fax ID: 40088

Chemical Decontamination With Preoxidation Steps: BWR Systems at Plant Hatch
TR-107165 Final Report (WO4419-2)
Contractor: PN Services
EPRI Project Manager: H. Ocken
FaxID: 40381

An Economic Analysis of Cobalt Valve Replacement Strategies
TR-107169 Final Report (WO4035-1)
Contractor: Decision Focus Inc.
EPRI Project Manager: H. Ocken
Fax ID: 40387

Experience With Depleted Zinc Oxide Injection in BWRs
TR-107188 Final Report (WO3419-1)
Contractor: GE Nuclear Energy
EPRI Project Manager: H. Ocken
Fax ID: 40419

Analysis and Confirmation of Robust Performance for the Flow-Diversion Barrier System Within the Yucca Mountain Site
TR-107189 Final Report (WO3294-17)
Contractor: QuantiSci, Inc.
EPRI Project Manager: J. Kessler
Fax ID: 40421

Low Level Waste Characterization Guidelines
TR-107201 Final Report (WO2691)
Contractor: Roy F. Weston, Inc.
EPRI Project Manager: C. Hornibrook
Fax ID: 40442

Study on High-Temperature Chemical Cleaning Tests and Applications
TR-107207 Final Report (WOS523-6)
Contractor: Key Chemical Processes
EPRI Project Manager: R. Thomas
Fax ID: 40462

An Assessment of Chromium Coatings to Reduce Radiation Buildup: 1996 Progress
TR-107224 Interim Report (WO2758-2)
Contractor: CENTEC XXI
EPRI Project Manager: H. Ocken
Fax ID: 40492

NOREM Applications Guidelines: Procedures for Arc Welding of NOREM Hardfacing Alloys
TR-107231 Final Report (WO1935-19)
Contractor: EPRI Repair and Replacement Applications Center
EPRI Project Manager: H. Ocken
Fax ID: 40506

Effect of Inhibitors on the Electric Resistance of Alloy 600 Surface Films
TR-107262 Final Report (WOS515-1)
Contractor: Technical Research Centre of Finland
EPRI Project Manager: A. McIlree
Fax ID: 40566

Steam Generator Tube Fatigue Evaluation
TR-107263 Final Report (WOS415-2, WOS540-1)
Contractor: Foster Wheeler Development Corp.
EPRI Project Manager: G. Srikantiah
Fax ID: 40568

Design/Characterization of New Low-Volatility pH Control
TR-107296 Final Report (WOS409-2, WOS510-1)
Contractor: San Diego State University Foundation
EPRI Project Manager: P. Millett
Fax ID: 40655

POWER DELIVERY

Distribution Engineering Workstation, Vol. 6: User's Manual, Version 1.1
EL-7249-V6 Final Report (WO3952-1)
Contractor: Electrical Distribution Design
EPRI Project Manager: H. Ng
Fax ID: 40166

Utility Benefits of SMES in the Pacific Northwest
TR-104802 Final Report (WO2572-13)
Contractor: Battelle Pacific Northwest
EPRI Project Manager: S. Eckroad
Fax ID: 23186

Broadcast and Multicast for Customer Communications and Distribution Automation
TR-106354 (see listing under Customer Systems)

Ground-Penetrating Imaging Radar System for Locating and Mapping Subsurface Structures: Phase I
TR-106399 Final Report (WO4029-1)
Contractor: Lockheed Martin Missiles and Space Co.
EPRI Project Manager: R. Bernstein
Fax ID: 25838

Field Operation Power Switching Safety
TR-106465 Final Report (WO2944-10)
Contractor: General Physics Corp.
EPRI Project Manager: G. Cauley
Fax ID: 40223

Slow Release of Fungicides for Wood Pole Applications
TR-106634 Final Report (WO2881-2)
Contractor: Southwest Research Institute
EPRI Project Manager: B. Bernstein
Fax ID: 26196

Distribution Grounding Analysis Program, Vol. 2: Programmer's Manual
TR-106661-V2 Final Report (WO3066)
Contractor: Canadian Electrical Association
EPRI Project Manager: H. Ng
Fax ID: 40218

Distribution Grounding Analysis Program, Vol. 3: User's Manual
TR-106661-V3 Final Report (WO3066)
Contractor: Canadian Electrical Association
EPRI Project Manager: H. Ng
Fax ID: 40219

Valuing Generation Assets in Uncertain Markets II: Tracing the Forward Curve
TR-106879 Final Report (WO4024)
EPRI Project Manager: R. Goldberg
Fax ID: 26619

Preparing the Ground for Pricing Unbundled Electricity Services: The Importance of Markets
TR-106933 Final Report (WO2801)
Contractor: Christensen Associates
EPRI Project Manager: C. Smyser
Fax ID: 39896

Development and Testing of a 38-kV Current Limiting Protector
TR-106992 Final Report (WO1142-3)
Contractor: Phoenix Electric Corp.
EPRI Project Manager: R. Samm
FaxID: 39984

Advanced GTO Development
TR-107012 Final Report (WO2443-2)
Contractor: General Electric Co.
EPRI Project Manager: M. Wilhelm
Fax ID: 40010

Development of a V_{BO} Function in a Light-Triggered Thyristor
TR-107013 Final Report (WO2443-1)
Contractor: General Electric Co.
EPRI Project Manager: M. Wilhelm
Fax ID: 40012

Inter–Control Center Communications Protocol (ICCP) User's Guide
TR-107176 Final Report (WO4379-1)
Contractor: KEMA-ECC
EPRI Project Manager: D. Becker
Fax ID: 40396

STRATEGIC R&D

Guidelines for the Evaluation of Seam-Welded High Energy Piping
TR-104631 Final Report (WO8046-4, WO2819-24)
Contractor: Westinghouse Electric Corp.
EPRI Project Managers: R. Viswanathan, R. Tilley, B. Dooley
Fax ID: 22420

Assessment of the Ray Diagram
TR-106017 Final Report (WO8034-10)
Contractor: Oak Ridge National Laboratory
EPRI Project Manager: B. Dooley
Fax ID: 25151

Proceedings: Electroseparations 2020 Workshop
TR-106434 Final Report (WO8060-1)
Contractors: Lockheed Martin Energy Systems, Inc./Oak Ridge National Laboratory; Barr Enterprises
EPRI Project Manager: A. Amarnath
Fax ID: 25901

The Use of Solid Electrolytes in Heterogeneous Catalysis
TR-106578 Final Report (WO8060-9)
Contractors: Institute of Chemical Engineering and High Temperature Chemical Processes; Foundation of Research and Technology (Hellas, Greece)
EPRI Project Manager: F. Kalhammer
Fax ID: 26117

Process-Induced Stresses in Laminated Composites
TR-107007 Final Report (WO8007-22)
Contractor: University of Washington
EPRI Project Manager: B. Bernstein
Fax ID: 40001

EPRI Events

MAY

6–8
Fish Passage Workshop
Milwaukee, Wisconsin
Contact: Maggie Loobey, (415) 855-2158

7–9
Midas Users Group Meeting
Phoenix, Arizona
Contact: Susan Marsland, (415) 855-2946

8–9
Energy Reservation and Scheduling Course
Minneapolis, Minnesota
Contact: Denise Wesalainen, (415) 855-2259

9
Chaos and Nonlinear Dynamics Tutorial and Workshop
Palo Alto, California
Contact: Martin Wildberger, (415) 855-1043

12–13
Continuous Emissions Monitoring Stack-Testing Observation Course
Denver, Colorado
Contact: Michele Samoulides, (415) 855-2127

12–13
Energy Reservation and Scheduling Course
Philadelphia, Pennsylvania
Contact: Denise Wesalainen, (415) 855-2259

12–16
Steam Plant Operations for Utility Engineers
Kansas City, Missouri
Contact: Amy Winn, (816) 235-5623

13–14
2d Annual Green Pricing Workshop
Corpus Christi, Texas
Contact: Lori Adams, (415) 855-8763

13–14
Strategic Asset Management: More Applications and New Results
Phoenix, Arizona
Contact: Vic Niemeyer, (415) 855-2744

13–16
Feedwater Heaters Short Course
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

14–15
Woodpecker Resistance Workshop
Charlotte, North Carolina
Contact: Bruce Bernstein, (202) 293-7511

14–16
1997 Continuous Emissions Monitoring Conference
Denver, Colorado
Contact: Michele Samoulides, (415) 855-2127

19–21
Reliability-Centered Maintenance for Power Delivery Equipment
Dallas, Texas
Contact: Denise Wesalainen, (415) 855-2259

19–22
Nondestructive Evaluation for Fossil Plants
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

20–22
Effects of Coal Quality on Power Plants
Kansas City, Missouri
Contact: Susan Bisetti, (415) 855-7919

20–22
Lubrication Oil Analysis
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

20–23
Alumitech '97
Atlanta, Georgia
Contact: Joe Goodwill, (412) 268-3435

21–22
2d Annual Global Climate Research Seminar
Washington, D.C.
Contact: Tom Wilson, (415) 855-7928

21–23
Constructing and Using Forward Price Curves
Washington, D.C.
Contact: Vic Niemeyer, (415) 855-2744

22–23
Transmission Inspection and Maintenance System
Fort Worth, Texas
Contact: Kathleen Lyons, (415) 855-2656

28–29
Energy Reservation and Scheduling Course
Atlanta, Georgia
Contact: Denise Wesalainen, (415) 855-2259

JUNE

2–4
CHECWORKS Users Group Meeting
Myrtle Beach, South Carolina
Contact: Christine Lillie, (415) 855-2010

3–4
Energy Reservation and Scheduling Course
Redondo Beach, California
Contact: Denise Wesalainen, (415) 855-2259

3–4
Generator and Electrical Testing Course
Toronto, Canada
Contact: Denise Wesalainen, (415) 855-2259

3–5
Infrared Thermography: Level 3
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

3–6
Diesel Generator Owners Group Conference
Chicago, Illinois
Contact: Linda Suddreth, (704) 547-6141

3–6
Pressure Relief Valve Application, Maintenance, and Testing
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

4
Water and Energy Conference
Cleveland, Ohio
Contact: Kim Shilling, (314) 935-8590

5–6
Municipal Water and Wastewater Program
Cleveland, Ohio
Contact: Kim Shilling, (314) 935-8590

10–12
5th International Conference on Cycle Chemistry in Fossil Plants
Charlotte, North Carolina
Contact: Michele Samoulides, (415) 855-2127

10–12
Predictive Maintenance Program: Development and Implementation
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

10–13
Healthcare Initiative Workshop and Conference
Chicago, Illinois
Contact: Janis Prifti, (415) 641-8332

11–13
8th National Energy Services Conference and Exposition
Washington, D.C.
Contact: Elliot Boardman, (561) 361-0023

15–18
7th International ISA POWID/EPRI Controls and Instrumentation Conference
Knoxville, Tennessee
Contact: Susan Bisetti, (415) 855-7919

16–19
Power Quality Conference: PQA '97 Europe
Stockholm, Sweden
Contact: Lori Adams, (415) 855-8763

17–19
Price-Product Mix Analysis and Workshop
Charleston, South Carolina
Contact: Christine Lillie, (415) 855-2010

17–20
Heat Exchanger Performance Prediction
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

19–20
EPRI Partnership for Industrial Competitiveness
Chicago, Illinois
Contact: Bill Smith, (415) 855-2415

20
Data Compression and Signal Transmission Tutorial and Workshop
Palo Alto, California
Contact: Martin Wildberger, (415) 855-1043

23–25
1997 Technology Delivery Workshop: Targeting Technology for Strategic Advantage
San Francisco, California
Contact: Christine Lillie, (415) 855-2010

23–26
4th International Conference on Biochemistry of Trace Elements
Berkeley, California
Contact: Leonard Levin, (415) 855-7929

24–25
Electromagnetic Interference Analysis
Columbus, Ohio
Contact: Susan Bisetti, (415) 855-7919

24–27
Check Valve Application, Maintenance, Monitoring, and Diagnostics
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

24–27
Steam Turbine Performance Monitoring, Diagnostics, and Improvement
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

JULY

8–9
Detection and Control of Flow-Accelerated Corrosion in Fossil Plants
Philadelphia, Pennsylvania
Contact: Christine Lillie, (415) 855-2010

14–16
Power Quality Technical Training
Knoxville, Tennessee
Contact: Lisa Nederhoff, (423) 570-8014

14–16
6th EPRI Valve Technology Symposium
Portland, Maine
Contact: Susan Otto, (704) 547-6072

14–18
Steam Plant Operations for Utility Engineers
Castine, Maine
Contact: Ginny Commiciotto, (207) 326-2212

15–17
Motor Rewind Seminar
Charleston, West Virginia
Contact: Denise Wesalainen, (415) 855-2259

21–23
1997 International Low-Level-Waste Conference
Providence, Rhode Island
Contact: Michele Samoulides, (415) 855-2127

23–25
EPRI/ASME Radwaste Workshop
Providence, Rhode Island
Contact: Michele Samoulides, (415) 855-2127

28–August 1
Terry Turbine Workshop
Houston, Texas
Contact: Linda Suddreth, (704) 547-6141

29–31
Fluid-Film Bearing Diagnostics
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

29–August 1
5th EPRI Steam Turbine–Generator Workshop
Lake Buena Vista, Florida
Contact: Paul Sabourin, (704) 547-6155

AUGUST

5–7
Acoustic Emission Monitoring of Reheat Piping
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

8
Risk Analysis and Financial Mathematics Tutorial and Workshop
Palo Alto, California
Contact: Martin Wildberger, (415) 855-1043

11–12
Nuclear Plant Performance Improvement Seminar
San Antonio, Texas
Contact: Bruce Lube, (704) 547-6080

11–14
Cooling Tower Conference
St. Petersburg, Florida
Contact: Susan Bisetti, (415) 855-7919

12–15
Generator Monitoring and Diagnostics
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

12–15
Motor Monitoring and Diagnostics
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

18–22
Steam Plant Operations for Utility Engineers
Castine, Maine
Contact: Ginny Commiciotto, (207) 326-2212

23–25
Power Plant Pumps Short Course
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

25–27
1997 EPRIweb Conference
Washington, D.C.
Contact: Michele Samoulides, (415) 855-2127

25–29
SO_2/NO_x/Particulates/CEM Symposium
Washington, D.C.
Contact: Lori Adams, (415) 855-8763

27
Workshop on Business Practices for Environmental Excellence
Denver, Colorado
Contact: Mary McLearn, (415) 855-2487

SEPTEMBER

8–10
Electric Motor Predictive Maintenance
Chesterfield, Missouri
Contact: Christine Lillie, (415) 855-2010

9–12
Basic Vibration Testing and Analysis
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

10–12
Value and Risk in Competitive Markets
Denver, Colorado
Contact: Susan Bisetti, (415) 855-7919

15–17
1997 Condensate Polishing Workshop
New Orleans, Louisiana
Contact: Barbara James, (707) 823-5237

16–19
Lubrication and Bearing Workshop
Albuquerque, New Mexico
Contact: Linda Suddreth, (704) 547-6141

16–19
Transformer Performance, Monitoring, and Diagnostics
Long Beach, California
Contact: John Niemkiewicz, (800) 745-9982

22–26
Infrared Thermography: Level 2
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

24–25
Lightning Protection Design Workstation Version 4.0 Workshop
Dallas, Texas
Contact: Vito Longo, (415) 855-8586

26
Rough Sets and Fuzzy Logic Tutorial and Workshop
Palo Alto, California
Contact: Martin Wildberger, (415) 855-1043

30–October 3
Steam Turbine Performance Monitoring, Diagnostics, and Improvement
San Antonio, Texas
Contact: Jeanne Harris, (800) 745-9982

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