Research Progress Review

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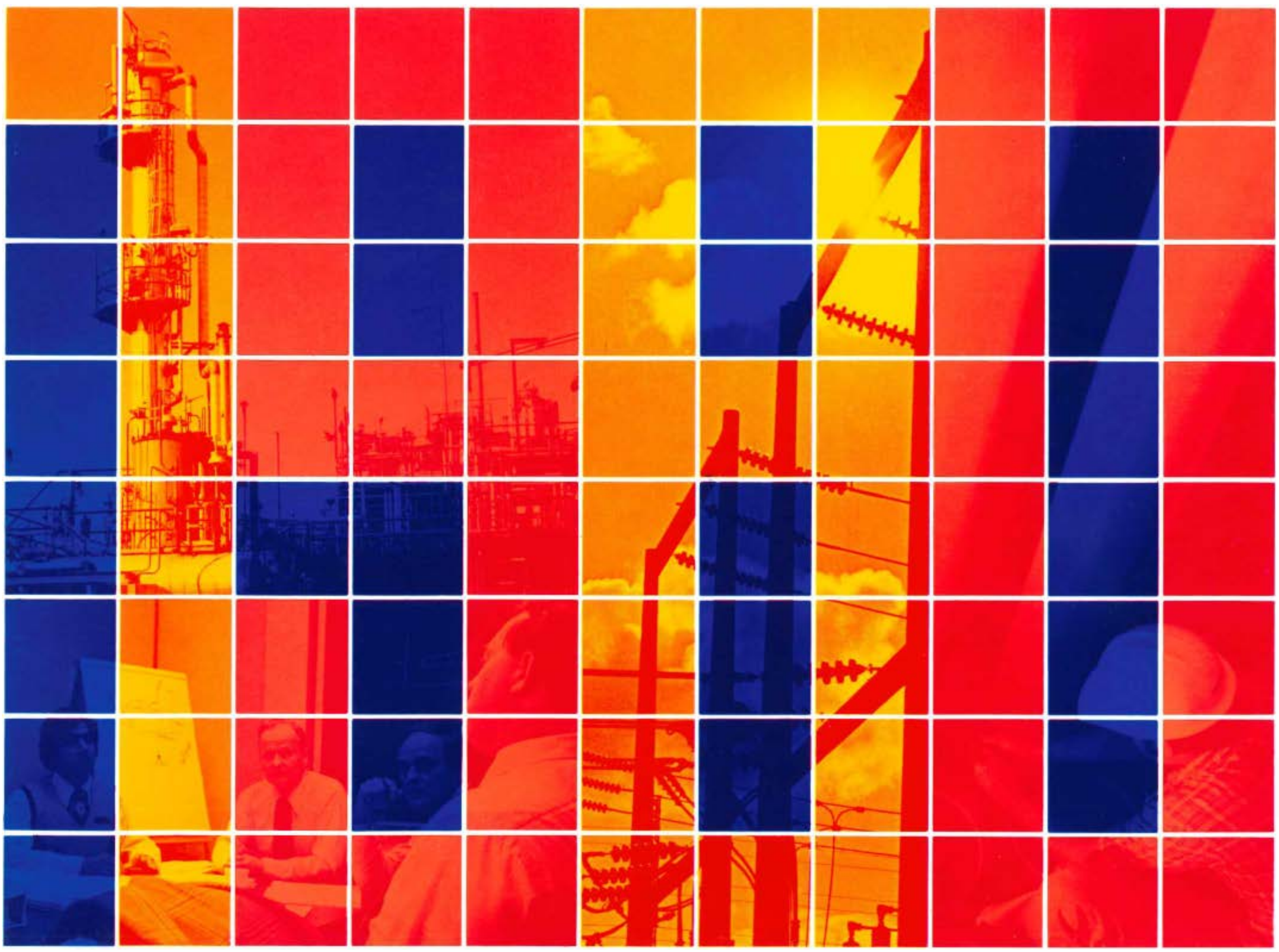

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About This Issue

EPRI now sponsors some 1200 research projects on behalf of its member utilities. The work is far-ranging but shares the common purpose of providing information and technology to meet the needs of existing systems and to develop advanced alternatives that will allow the expansion of those systems. At the insistence of its sponsoring organizations, an increasing percentage of the work is now devoted to near-term R&D, that is, to hardware and systems that can be delivered within the next decade.

As a result of this pressing mandate to deliver and the breadth of activity, information and technology are now beginning to flow from EPRI contractors at an accelerating rate. But this proliferation presents new problems—notably, how to integrate, assimilate, and transfer the results to the utility systems.

EPRI President Floyd Culler leads off this year's review issue of the *EPRI Journal* by addressing this emerging problem of technology transfer. Our tools, he points out, are the traditional ones of people and paper, and these in today's climate of rapid change may not be fast enough or even sufficient. More rapid and less diffuse approaches are being explored.

Familiarity and exposure are the first steps in technology transfer, and the *Journal* has devoted this issue to an overview of some four dozen representative projects and to a distillation of the Institute's five-year plan. It is hoped that these pages will help to inform the reader about EPRI's R&D strategy, program plans, and some of the key research results that will be forthcoming in the 1980s.

EPRI JOURNAL

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January/February 1981

by Floyd Culler

STEWARDSHIP: THE DUTIES BEYOND R&D

EPRI's responsibility begins with research but it doesn't end with development. The Institute encourages timely utility action in transferring new technology to the minds and hands that can use it. And EPRI coordinates utility interests in a growing number of large, shared projects to demonstrate new technology at representative scale.

Good stewardship in research and development requires the expansion of knowledge and the creation of new technology to solve existing and future problems. EPRI is, in a sense, the steward for the utility industry: it is responsible for seeing that effective R&D is accomplished—and its results applied wherever beneficial.

EPRI's programs are planned to produce results that can be used in the near term. Indeed, between 50 and 60% of our funds are targeted to develop techniques or equipment that can be commercially available within 5–10 years. (Another 30–45% of our funding goes into intermediate-term technology that may mature in 10–25 years. Only 5–10% is for long-term research, where the application is expected to be more than 25 years away.) Thus, with 7 years of work behind us, there is now a rapidly growing body of knowledge and technology coming from EPRI-sponsored R&D. It is ready for transfer into utility minds and hands. How is that process to be stimulated?

We encourage our members to regard EPRI as a primary information source when equipment is purchased, when a generation system is planned, or when a problem with process emissions or wastes must be solved. We can help with systems to improve reliability and on-stream time; we can help with conservation programs, with new criteria for the design of transmission lines, generators, transformers, capacitors, switches, and relays. In short, our staff is a clearinghouse, broadly acquainted with potential solutions currently available, not only from our own work but also from that of others.

There is a special reason that we and our member utilities must develop a sense of urgency in using R&D results. Much of what we consider to be practical, useful technology does not age well. It has its season and can best be used when the developers are still keen and poised to manufacture or build. Unless used and honed, this sharpness corrodes with time. What remains is not a cutting edge but only libraries of paper reports. Dull indeed.

Thus, a quality of successful stewardship is to ensure that R&D results are regularly recognized, evaluated, and applied where they are most useful.

In this technology transfer, EPRI is primarily responsible for making information available in a timely manner to each utility. So far, we have been using standard methods of dissemination. But research reports, seminars, papers, and workshops are not enough to accelerate the transfer of knowledge to the host of potential users. We must ask for help from each utility so that together we can seek ways of routing information about useful technology to the appropriate person. That individual, in turn, must talk with our staff and our contractors if EPRI's generic solutions are to be adapted to the needs of a particular utility. Technology transfer, while initiated by the publication of general information in reports, must be consolidated between knowledgeable individuals. It is therefore necessary to devise more advanced, or at least different, schemes for establishing successful technology-transfer relationships between EPRI and each member utility.

During this year, EPRI will seek assistance in learning the professional specialties of selected individuals in each company who will receive appropriate EPRI report summaries. We will have regional information meetings to review our overall program. Videotaped memoranda on specific subjects will be made available. By these new approaches we hope to establish personal contacts between utility managers who have technical problems and research managers who have technical solutions. Until our approach to this communication problem evolves clearly, you may wish to remember to "ask EPRI" before initiating new expansion, repairs, or replacements.

In addition to the near-term solutions pouring from many of EPRI's approximately 1200 projects, a number of jointly funded and managed pilot plant and demonstration facilities are now well along in design and construction; some are operating. Also either under construction or operating are test centers for supplying special and previously unavailable services to the utility industry: a coal-cleaning test facility, an NDE center, a transmission line mechanical research facility, an emissions control and test facility, among others. Three greatly improved flue gas scrubbers are being built for demonstration at ~100-MW scale. A gasification–combined-cycle project is about to enter its second design phase. Two demonstration plants for coal liquids began operation in 1980: the Exxon Donor Solvent process and the H-Coal process. The solvent-refined coal process has been significantly improved in a small EPRI pilot plant. The Battery Energy Storage Test Facility is soon to be dedicated; the first prototype battery for utility load leveling should be installed by year-end. The 4.5-MW fuel cell demonstration module is nearing completion, and greatly improved cell internals are well along (to be added a year or so after initial operation). A 45-MW binary-cycle geothermal power plant is authorized; a 20-MW atmospheric fluidized-bed combustion pilot plant is under construction.

Altogether, EPRI and other sponsors are participating in demonstrations valued at about $1.6 billion for construction and early operation. Of this total, about $500 million will be EPRI funds. Utilities, manufacturers, architect-engineers, the Department of Energy, and other agencies (including some from other nations) share the rest, either in money or in facilities and services.

Perhaps the most important EPRI work for the long term is environmental research. One example is the series of sponsored reviews of several federal studies of air pollutants and human health. Contrary to the original research, these reanalyses continue to show no significant epidemiological correlation between sulfur oxides and human health. Another example is the issue of acid rain and its effects on the environment. To determine the role of sulfur and nitrogen oxides from utility fossil fuel plants in this phenomenon, we are following the effects of rain at various lakes in eastern and western states, coordinating sample collection and analyses at over 30 stations, and arranging to coordinate acid rain data analyses among utilities and, where agreeable, with state and federal programs. A related and promising hardware development under EPRI sponsorship is a fuel burner in which combustion temperatures are controlled so as to reduce the formation of nitrogen oxides below the maximum concentrations proposed by the Environmental Protection Agency.

In nuclear power, the efforts of EPRI's Nuclear Power Division remain concentrated on the safety and operability of light water reactors. We are also beginning to consider how best to participate in a reactivated national breeder reactor development program, but a specific role awaits clear policy expression from the new federal administration.

Under EPRI's guidance, the Nuclear Safety Analysis Center (NSAC) is producing timely analyses of safety issues in response to regulatory requirements and from methodical monitoring of 300–400 reactor incident reports each month. (Perhaps three or four of these reports have some safety significance and one, on the average, calls for in-depth review.) NSAC operates a telecommunication network by which all nuclear utilities can stay apprised of these activities.

Thus, the R&D programs initiated seven years ago are now yielding a great range and quantity of useful technical results. Stewardship and plain Yankee good sense say that we must cooperate in reviewing, selecting, and applying these results, rapidly and widely, toward the efficient production of electricity at the lowest possible cost and with minimum adverse effects on the environment and human health.

RESEARCH PROGRESS REVIEW

EPRI was formed in 1972 to coordinate a national R&D program on behalf of its member utilities. Concentration in the first few years was on hiring staff, establishing the advisory structure, formulating scope and priorities, and putting the R&D programs in place. The common perception in those early years was that most programs would be directed toward future options, systems, and technologies that could be of value after the turn of the century. Tangible payoff was intentionally protracted.

But the Institute's strategy has evolved considerably in the past few years in direct response to utility needs and priorities and to the changing climate of energy in the United States. Today, EPRI's activities are focused on technical developments whose potential payoff can be anticipated within the next 10 years. This shift in focus has begun to accelerate the flow of useful information, discrete pieces of hardware and software, and the demonstration of major systems that will form the basis for future capacity additions and improvements in utility operations.

Some 1200 research projects are currently in progress under EPRI contract. On the following pages are capsule summaries of some four dozen representative projects drawn from the full constellation. For the convenience of the reader, these have been categorized as past, present, and future. This is, at best, an artifice because research is a continuum; most of the work shown as past is still undergoing refinement as it enters commercial application. Nevertheless, the division does point to the time of critical milestones. What is most important is that the initial payoff from these projects will be in the 1980s.

Glancing Back: Selected Accomplishments

Compact Transmission

Because utilities need to upgrade transmission capacity along existing power corridors and as rights-of-way for new lines are so expensive (not to mention the esthetic desirability of low, slender profiles for towers and lines), research toward closer conductor spacing was an early EPRI priority. It led to the 1978 publication of the *Transmission Line Reference Book, 115–138-kV Compact Line Design* (EL-260).

Research and tests underlying the report established the feasibility of 3-ft spacing between phases instead of the 10-ft spacing in conventional design. Recognized in the National Electric Safety Code, compact transmission criteria were first adopted by Utah Power & Light Co. Even with a conservative 6-ft phase spacing, the utility will save at least $40,000 (present value) in revenue requirements as it upgrades 40 miles of line during the years 1978–1982. (RP260)

Pinpointing Reliability

Using the hot exhaust gases from several combustion turbines to generate steam for a steam turbine, a combined-cycle power plant should prove economical for baseload power generation because its high thermal efficiency offsets high liquid or gaseous fuel costs. But reliability has been a question, with combustion turbine plants today exhibiting a mean time between failures (MTBF) of as little as 200 hours.

However, two years of EPRI-sponsored research by General Electric Co., United Technologies Corp., and Westinghouse Electric Corp. found that most equipment failures occur in plant auxiliaries and can be rapidly corrected. Thus, considering only the combustion turbine portion of a combined-cycle plant, availability today averages about 92%, with nearly 1000 hours MTBF. Analysis of the predominant failure modes is guiding R&D on new turbine systems with the objective of achieving 6000 hours MTBF with an estimated overall combined-cycle plant reliability of 3000 hours. (RP1187)

Enough Uranium?

Nuclear power growth projections in the mid-1970s raised concern over the future availability and price of uranium and were a factor in the dramatic price rise of yellow cake from $8 to more than $40 a pound. Uranium supply questions influenced the urgency of utility R&D on a breeder reactor and on the recovery of plutonium from spent reactor fuel. Projections and conjecture also influenced cost comparisons of future nuclear and coal-fired power plants.

In this climate EPRI sponsored a number of studies to evaluate the understanding of uranium geology, assess resource estimation methodologies, test several promising exploration techniques, develop engineering models to calculate the costs of uranium mining and milling, examine the price history of uranium, and review the outlook for foreign uranium supplies. (RP803, RP883)

Geothermal Heat Exchange

Nearly half the energy available from U.S. geothermal resources is in waters with temperatures between 150°C and 210°C. Because the energy content at these temperatures is low, heat recovery and conversion must be highly efficient for significant utility electricity generation, even with expansion turbines that use low-boiling fluids. Since 1974, therefore, EPRI has sponsored research on heat transfer from geothermal brine, beginning with 500-hour heat exchanger tests performed by San Diego Gas & Electric Co.

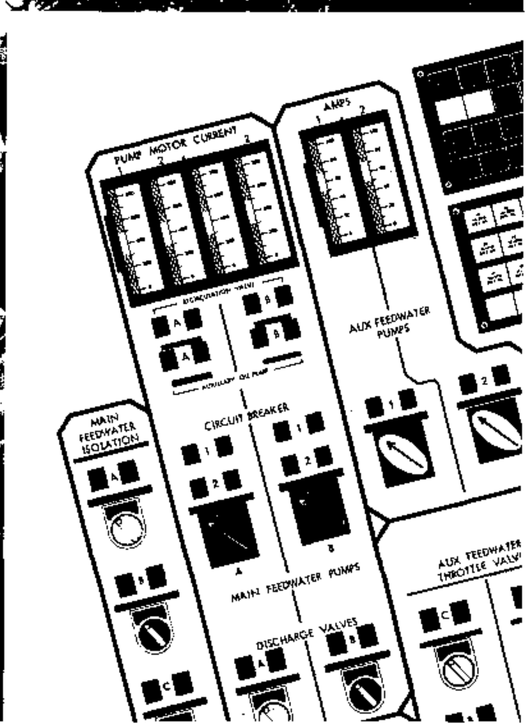
Tests at Heber, California, by The Ben Holt Co. in 1976–1977 extended the experience to 2000 hours, evaluated the deposition rate and composition of brine scale in mild carbon steel and titanium tubes, and produced data for projecting heat exchanger performance over longer time periods. Since 1979 a complete 6-MW (th) module (including brine, isobutane, and cooling water loops) has been operated at East Mesa by Colley Engineers & Constructors, Inc. The research findings are being incorporated into the design of a 45-MW (e) binary-cycle geothermal demonstration plant to be built at Heber with funding by EPRI, DOE, San Diego Gas & Electric, and others. (RP376, RP846, RP1094)

Better Control Rooms

Even though utility system disturbances and outages are eventually described in terms of equipment malfunction or failure, research results show that more than 20% of all instances are caused or aggravated by inappropriate responses at the man-machine interface. Many such human factors problems involve the equipment for data handling and display in power plant control rooms.

Extensive EPRI-sponsored

Compact transmission line in Utah.



Control panel marked to show instrument groups.

Open-pit uranium mine in Wyoming.

Glancing Back

research begun in 1975 particularly addressed human engineering practices and criteria in nuclear plant control indicators, panels, consoles, and entire rooms. Problems were exhaustively cataloged and analyzed; considerations were developed for use in advanced designs; and a number of cost-effective modifications were devised for use in existing control rooms. A dramatic example is the use of tape or paint-stripe borders to surround functionally related panel indicators and controls. (RP501)

End-Use Energy Efficiency

Because heat pumps can deliver about three units of heat energy for every one unit of electric energy expended at 50°F (10°C), they should be an effective energy saver for utilities and their customers. But on colder days, the auxiliary electric resistance elements in today's heat pumps push power consumption up, wiping out much of the energy savings.

EPRI-sponsored research begun in 1975 showed that properly installed heat pumps can deliver energy at a seasonal average performance factor of 2 or more, even in northern climates. Later studies pointed out that two-speed motors or dual compressors (now commercially available and being field-tested by EPRI) can boost the performance factor to 2.5 or better. Recent research suggests that hybrid installations linking heat pumps with hot-air furnaces yield an economical combination of electricity and gas or oil use that reduces the consumption of scarce heating fuels. (RP544, RP789, RP1201)

Advanced SRC

If solvent-refined coal processes are to yield economical and clean-burning fuels, they must accommodate a wide variety of coals and operate at the least severe conditions of time, temperature, and pressure. During seven years of pilot-scale research operations at Wilsonville, Alabama, the keys to these objectives have been identified: the composition of the solvent fraction recovered for reuse and the means to isolate it.

Critical solvent de-ashing was originally tested as a two-stage process that would remove ash and solid residue from the SRC reaction products more reliably than filtration. It was modified under EPRI guidance by adding a third stage to permit selective recovery of process liquids that promote hydrogenation when recycled. The technique will improve the operation of the SRC-I process in DOE's 6000-t/d demonstration plant.

The Wilsonville research, hosted by Southern Company Services as prime contractor, has been cosponsored by DOE since 1976 and augmented by numerous EPRI-sponsored contracts for laboratory research. (RF1234)

Retarding Tree Growth

The seasons pass, and in much of suburban America, trees will flourish again this spring along streets and property lines, spreading upward into power distribution lines, where they become a hazard and generate a substantial utility cost for pruning.

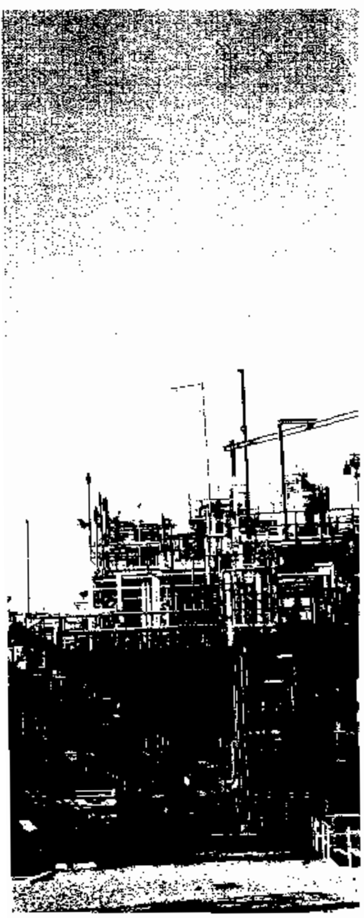
The trimming task may be required annually or as infrequently as every four years. For Ohio Edison Co. the average is every three years, but the company is now looking at a four-year cycle as it and 10 other utilities test two growth-retarding chemicals. The chemicals, Slo-Gro and Atrinal, selected from 11 candidates evaluated for EPRI by the Department of Agriculture since 1974, are injected into tree trunks with portable equipment developed during the research project. Only about 300 trees have been treated by Ohio Edison so far, but the utility estimates that expansion of the program to 40,000 trees a year by 1985 will yield levelized annual savings of at least $200,000. (RP214)

Guidelines for Feed Pumps

Auxiliaries in fossil fuel power plants account for nearly one-third of forced-outage availability losses, and boiler feedwater pumps are the second most important of these sources of loss. Two successive EPRI research projects since 1975 have documented the generic weaknesses in feed pump design and have produced guidelines for utility use in specifying pumps based on the cost of their reliability-related design features.

The initial effort by Energy Research & Consultants Corp. featured a survey and analysis of the operating histories of 1200 feed pumps and documented some 3000 failures. The contractor's data enabled Tampa Electric Co. to develop economic weighting factors for seven major causes of failure. Using the factors when evaluating pump bids for a new plant, Tampa Electric chose a design that was calculated to be 57% more reliable than the average. With the assistance and cooperation of the Edi-

Treated and untreated trees in test of growth retardant.



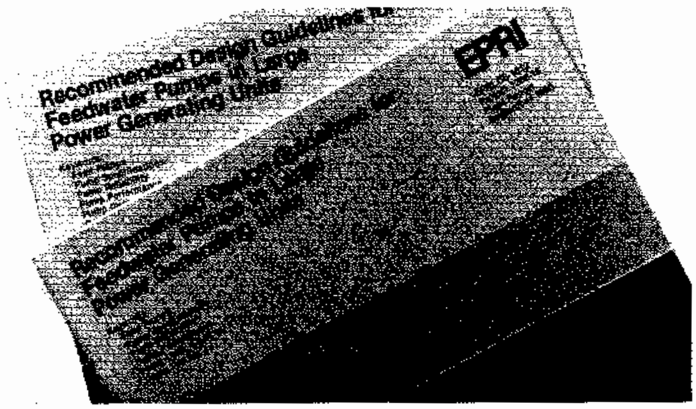
SRC pilot plant at Wilsonville, Alabama.

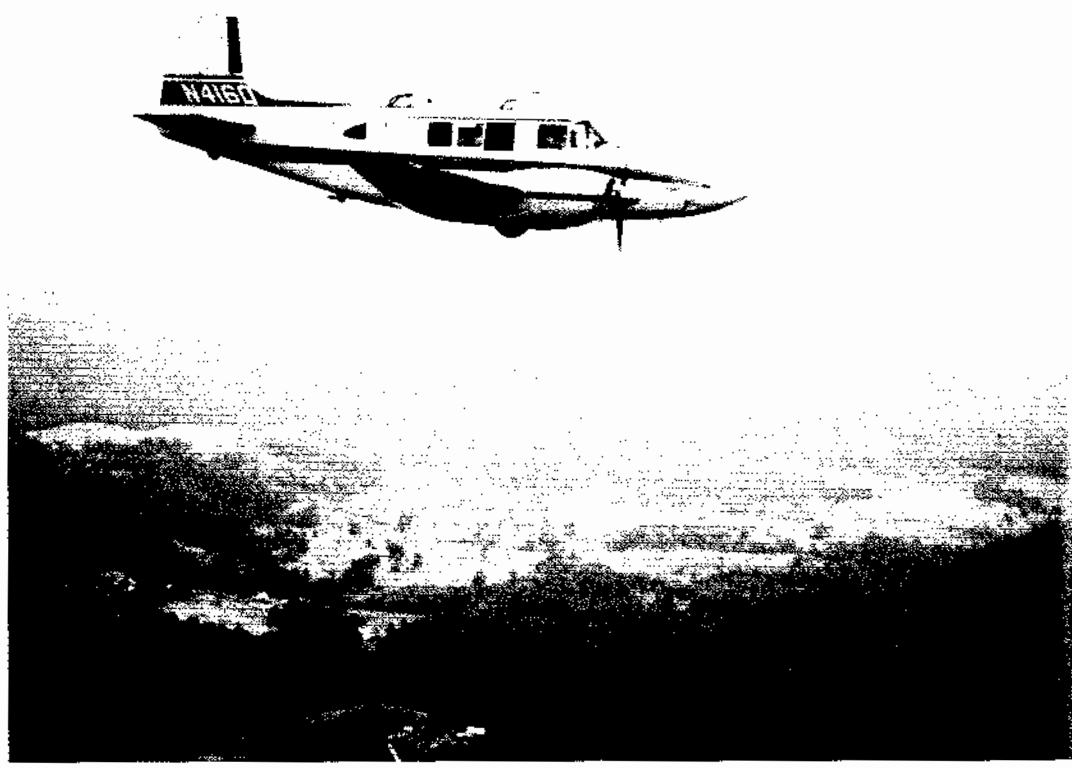
Benefits of energy efficiency in the home.

Manual for evaluating boiler feedwater pumps.

Acoustic sensor to measure valve leakage.

Airborne instrumentation for sampling air quality.





Glancing Back

son Electric Institute's Prime Movers Committee, EPRI has since published *Recommended Design Guidelines for Feedwater Pumps in Large Power Generating Units* (CS-1512). (RP641, RP1266-18)

Sulfate Connection Questioned

Conducted between 1967 and 1975, the federal government's Community Health Evaluation Surveillance System research (the CHESS studies) contributed to EPA's proposed revisions of standards for airborne sulfur dioxide (SO_2) concentrations and was cited as the basis for a national sulfate standard. But Congress and other groups questioned the certainty of some CHESS conclusions, and although the role of power plant SO_2 emissions in the formation of airborne sulfates has been acknowledged, it has not been quantified. Therefore EPRI commissioned reanalyses of some 20 sets of CHESS data. The work has shown that many of the original data were flawed, particularly by incomplete analysis that did not adjust for socioeconomic and study design factors. Accepted by later reviewers, the reanalyses show no clear association between SO_2 or sulfate concentrations and human health effects. (RP686, RP1316, RP1642)

Regional Air Quality

Defining the relationship between SO_2 emissions from power plants and sulfate concentrations in the ambient air and rain was the objective of the six-year, $7 million Sulfate Regional Experiment (SURE) begun in 1974. Results of the research should be useful in designing corrective action if and when ambient levels of sulfates (and associate pollutants) are linked with human health or other effects on the environment.

The most extensive data were collected throughout the northeastern United States between August 1977 and December 1978. Nine primary stations accumulated daily records, and 45 secondary stations (plus two planes) took data during the six months selected as seasonally typical. Emission sources were also inventoried seasonally.

Environmental Research & Technology, Inc., and other EPRI contractors are now completing their data analyses, finding occasional widespread increases in atmospheric sulfate levels during the monitored period but noting that day-to-day changes are primarily weather-related and thus difficult to link quantitatively with SO_2 emission volume. Sulfate levels in nonurban areas are lower than expected (earlier measurements having been mainly in cities), with 95% of the reported values being less than 20 $\mu g/m^3$. (RP862)

Monitoring Relief Valves

Once a steam relief or safety valve begins to leak, the safety of a nuclear power plant could be compromised. The problem is to know if a particular valve is leaking, and if so, how serious the leak is. Research by Philadelphia Electric Co. revealed that flow-induced vibration of a valve body reliably indicates steam leakage and can be detected by acoustic means. Further research under EPRI sponsorship quantified the technique for BWR safety/relief valves, correlating acoustic data with valve leak rates.

Acoustic monitoring uses a simple accelerometer that straps on the valve body; it is thus inexpensive for retrofitting, and its use avoids drilling through piping or valve casings. As a reliable indicator of steam flow through relief valves of both PWRs and BWRs, the technique has been timely as an improvement in nuclear plants since the Three Mile Island accident. (RP1246)

Lime Scrubber Book

As air and water quality regulations evolve, utilities must upgrade and optimize the performance of emission control systems on fossil fuel power plants and identify the most advanced control technologies for use in new plants. Recognizing that nearly half the flue gas desulfurization (FGD) capacity installed or under construction by utilities involved lime scrubbers, EPRI commissioned the *Lime FGD Systems Data Book* (FP-1030) three years ago.

Published in cooperation with the Environmental Protection Agency, the report was released in mid-1979 as a guideline to the planning, specification, and operation of lime scrubbers. Reflecting the combined judgments of utilities, architect-engineers, and equipment suppliers, the book details design and performance parameters and selection criteria; it also sets forth procedures for site-specific weighting of parameters. In some utility applications, use of the book could yield operating savings of up to 30% through improved scrubber reliability and reduced maintenance. (RP982-1)

Data book for lime scrubbers.

Equipment to isolate leaking condenser tubes.

Gypsum residue from Chiyoda scrubber test.

Glancing Back

Scrubber Performance

With pulverized coal increasingly evident as the major fuel for new utility power generation capacity in coming years, flue gas scrubbers are becoming the dominant means of controlling plant SO_2 emissions. Among the newer scrubbers evaluated under EPRI sponsorship, the Chiyoda Thoroughbred-121 earned a top rating on the basis of extensive tests of a 20-MW prototype unit at the Scholz station of Gulf Power Co. during 1978 and 1979.

Operated for eight months with a flue gas stream containing 1500–2000 ppm SO_2, the limestone slurry process showed a sulfur removal efficiency averaging 90% throughout the evaluation period. Scrubber availability was maintained at 97%, and limestone utilization was greater than 98%. The Chiyoda scrubber requires minimal freshwater makeup and produces nearly pure gypsum (calcium sulfate) as a by-product that stacks well, dewaters rapidly, and may have market value in wallboard manufacture and as a soil conditioner. (RP536)

Damping System Oscillations

Particularly when the segments of a utility transmission network are not densely interconnected, failure of one segment can create low-frequency (1–2 Hz) electrical oscillations that resonate, build in amplitude, and cause other segments to trip out in a cascading sequence. Construction of long-distance regional interconnections in the last 15 years has created many situations of low load density where oscillations cannot be damped by generator voltage regulation alone; protective measures must be designed and built in.

The necessary system analysis (applicable to new or existing systems) is now possible as a result of research performed under EPRI auspices by Westinghouse Electric Corp. Known as AESOPS 1 and 2 (analysis of essentially spontaneous oscillations in power systems), a pair of computer programs has been used by at least 10 utilities to model their systems and determine the character of oscillations likely to be produced by outages at various points. Several modifications can be modeled to determine their efficacy in system damping. The programs can be obtained from the Electric Power Software Center. (RP744)

Blowing Out an Arc

A puff of quickly compressed SF_6 insulating gas enhances the operation of a subtransmission (<72-kV) circuit breaker developed by Westinghouse Electric Corp. during the course of research for EPRI. In effect, the gas blows out the arc that occurs when the breaker opens. One type of gas-insulated breaker incorporates separate chambers of gas at different pressures for insulation and arc suppression. The puffer breaker, on the other hand, has a single chamber, but as the breaker opens, the action of a ported piston mechanism channels a momentary stream of gas across the contact area to inhibit arcing. The simpler configuration means lighter weight, lower cost, and less maintenance because arcs should restrike far less frequently.

Cost estimates have been made for replacing 12 oil-insulated breakers that switch shunt capacitor banks in Arizona Public Service Co. substations. During the period 1980–1984, the puffer breakers will yield investment savings of $20,000. (RP478)

Locating Condenser Leaks

A condenser tube leak of as little as a pint a day can induce corrosion somewhere in the feedwater and steam path of a power plant. Outage time to find and repair only one or a few among 10,000 tubes is costly but necessary if more costly corrosion damage is to be forestalled. Equipment developed in a $50,000 research effort uses helium or Freon gas as a leak tracer on successively smaller groups of condenser tubes until the leak is located. The new procedure is faster and more accurate than traditional use of foams, pastes, films, or audio or ultrasonic pressure detectors. Florida Power & Light Co., for example, has located leaks as small as 0.1 gal/d, incurring outage time of only five hours (including condenser drainage and refilling). The utility estimates that levelized savings in annual revenue requirements will exceed $250,000. (TPS78-775)

Building the Base: Milestones of 1980

Manhattan Fuel Cell

The fuel cell satisfies every requirement for power plant siting in urban locations: it is clean, quiet, and quickly installed in modular units. It is also efficient over a wide range of loads and quickly responds to load changes. It thus offers operating efficiencies and planning flexibility that help minimize utility investments. EPRI is a key sponsor of the 4.5-MW fuel cell demonstration in Manhattan on the system of Consolidated Edison Co. of New York, Inc. All power plant modules have been fabricated, and all modules needed to conduct the process and control check-out tests have been installed. The power plant is expected to be in operation in 1981, with performance validation tests completed in 1982. A similar power plant, but with upgraded power sections capable of 40,000 hours of operation, has been purchased by Tokyo Electric Co. and is also expected to be in operation in 1982. A fuel cell users group with 42 utility members is now working with manufacturers, EPRI, and the government to transfer the fuel cell to full commercial service by 1985. (RP842, RP1677, RP1777)

CONAC

Tightening SO_2 emission standards have compelled coal-burning utilities to either install flue-gas desulfurization equipment or to burn low-sulfur coal. In many cases, the least costly approach that can still satisfy emission requirements is to blend low-sulfur coal with more abundant high-sulfur coal. Until now, however, suitable equipment to permit economical blending was not available. EPRI research conducted by Science Applications, Inc., and Kennedy Van Saun Corp. has developed instrumentation and equipment that can quickly measure the composition and Btu value of a coal. Continuous analysis of coal (CONAC) uses neutron activation analysis to continuously meter the elements in coal and thus provides the means to automate coal handling and conveying equipment for optimal economic blending of coal. A prototype CONAC installation is scheduled for testing at a utility site in 1981. (RP983)

Solar Heating and Cooling

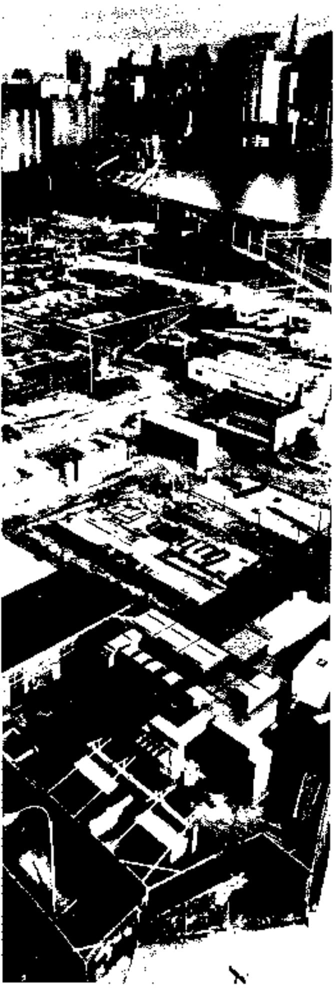
Data on solar heating and cooling (SHAC) system performance and economics are essential to utilities so that they can gauge the effects of these systems on backup energy demand for heating and cooling. By the end of 1980 EPRI's 10 residential solar demonstration homes produced high-quality data for two summers and one winter. Also, six commercial solar demonstrations were operational by the end of 1980. Data from these demonstrations are now being analyzed to identify the most effective SHAC systems, taking into consideration both the installed cost of solar and load management equipment and the cost to the utility of supplying backup energy. EPRI has cataloged over 70 SHAC computer programs and analyzed 12 of them to determine how well they meet utility requirements for serving their customers and providing long-term projections of customer energy demand; 4 of these programs have been tested, including EPRI's methodology for preferred solar systems. (RP549, RP1269)

STRAP, TREES, and BUCS

Turbine rotors are highly reliable components, with major failures occurring only once in several thousand turbine-years of operation. However, the costs of even such infrequent failures are significant. EPRI's research to improve rotor reliability through stress analysis, fracture mechanics, and nondestructive evaluation led to development of the steam turbine rotor analysis program (STRAP). This system enables utilities to predict rotor lifetime through duty cycle data, material properties, and inspection results. Because available ultrasonic bore inspection systems and procedures were found to be inadequate, contractor Southwest Research Institute developed the turbine rotor examination and evaluation system (TREES); Battelle, Columbus Laboratories developed the bore ultrasonic characterization system (BUCS). Both are compatible with STRAP. The three—STRAP, TREES, and BUCS—are available through EPRI license agreements. (RP502)

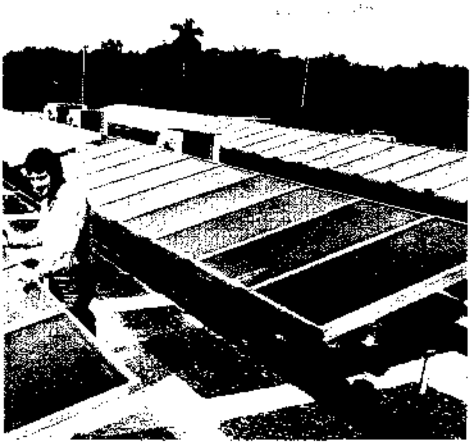
Transformer Improvement

EPRI has several projects under way related to improved transformer technology. Two of these deal with the aspects of electrical losses and cooling. In one project, EPRI and Allied Chemical Corp. have developed a new amorphous alloy for the manufacture of transformer cores. The alloy, a glassy metal, does not have the crystalline structure of conventional steels. This



The 4.5-MW fuel cell demonstration in New York City.

Typical substation on a utility system.



Solar heating and cooling demonstration at Florida Power & Light Co.'s Perrine Service Center.

characteristic increases its resistivity to eddy currents and hysteresis, thereby reducing electrical losses from the core by 60%. In another project, General Electric Co. and Westinghouse Electric Corp. are designing and building transformers with two-phase cooling (liquid and vapor). The objective is to cut fabrication costs and produce transformers that are fireproof, explosion-resistant, lighter, less dependent on oil, and environmentally acceptable. (RP1290, RP1499)

Baghouses

A key environmental problem facing the electric utility industry is the increased emphasis by regulatory agencies on high-efficiency collection of particulate emissions from pulverized-coal-fired boilers. In response, EPRI is conducting a major research program to develop fabric filters (baghouses) as a cost-effective particulate control option for utility power plants. A current research effort is the testing of a 10-MW fabric filter pilot plant at EPRI's Emissions Control and Test Facility at Arapahoe. Testing in progress will define the most effective bag cleaning techniques, appropriate fabrics and finishes, ductwork and compartment arrangements for minimum pressure loss, optimal selection of air-to-cloth ratio, and SO_2 removal capability with all-dry and spray-dry SO_2 removal systems. (RP1129)

Turbine Missiles

Steam turbine failures that could propel high-energy rotor fragments through the steel casing of power plant turbines are extremely unlikely. Nevertheless, the effects of such turbine missiles are considered in nuclear plant design. Full-scale, EPRI-sponsored rocket sled tests at Sandia National Laboratories in Albuquerque, New Mexico, have demonstrated that reinforced-concrete reactor containment buildings would be highly resistant to these postulated missiles and current design practices to minimize missile impact effects are conservative. For example, a 3250-lb turbine segment traveling 200 mph was stopped by a 4.5-ft-thick (1.4-m) reinforced-concrete wall with relatively little damage to the wall. Supplemented by analysis and scale-model tests, the full-scale tests are providing engineers with valuable information that can be used to support applications for plant licenses. (RP399)

Tower Foundations

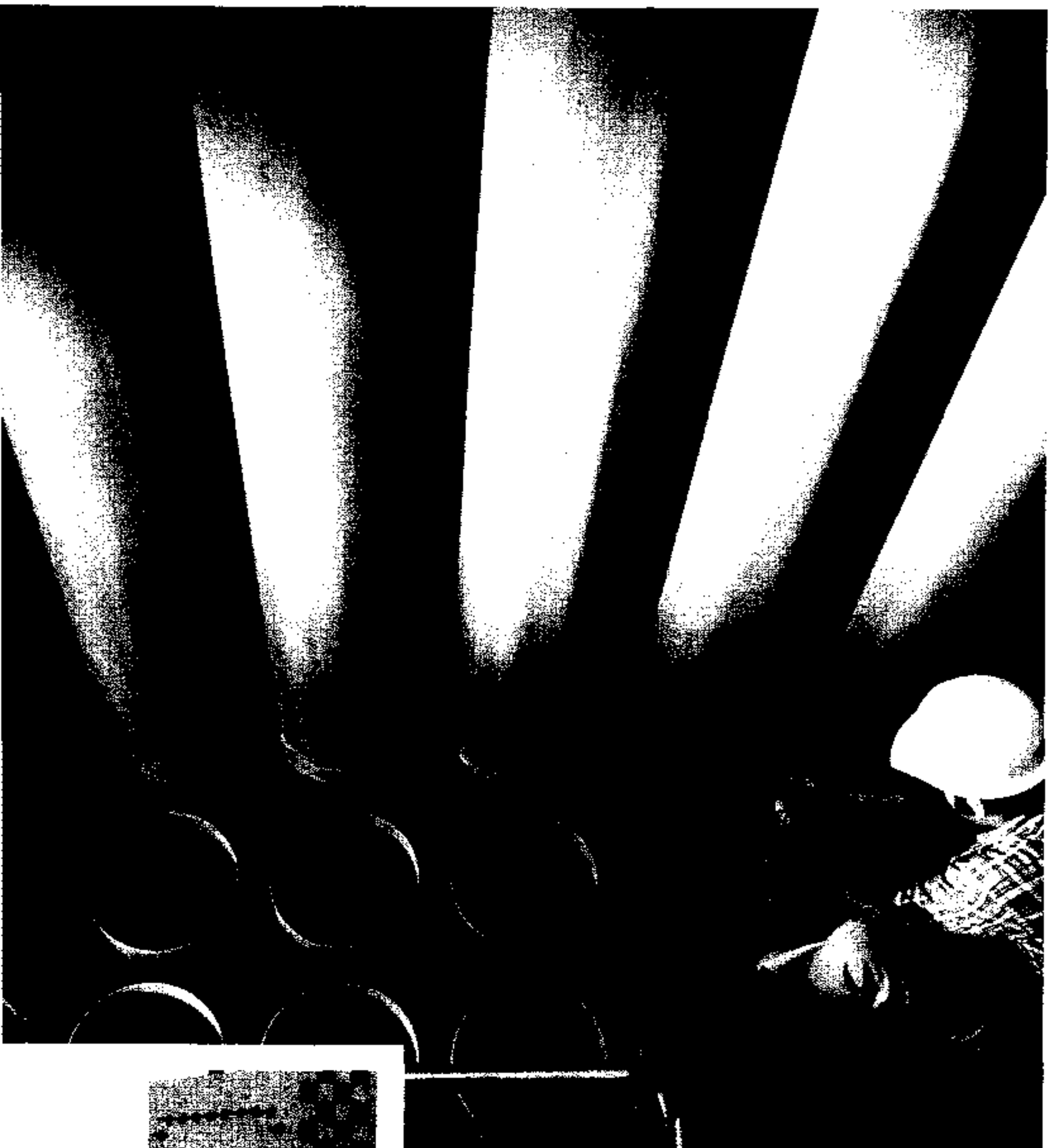
Reinforced-concrete foundations required to support transmission line towers make up a sizable portion of their overall cost, and utilities continue to seek ways to economize without sacrificing reliability. New and improved design methods for these foundations are needed to achieve these goals. Through its principal contractor, GAI Consultants, Inc., EPRI is developing an improved method for designing the foundations that are now used with single steel pole towers (laterally loaded, drilled piers). This method is being verified through a program of full-scale field tests on fully instrumented drilled piers installed in a wide variety of soils across the country. On completion of these tests in the summer of 1981, electric utilities should have the analytic tools for economically and reliably designing laterally loaded, drilled-pier foundations. (RP1280)

Airborne Particle Lidar

A two-wavelength particle-detecting device (lidar-based and called the ALPHA-1 system) to measure haze and atmospheric particle distributions was developed and field-tested during 1980. Lidar is similar to radar but emits pulsed laser light instead of microwaves. The ALPHA-1 system, which is available for industry use, has been used to map plume trajectories and dimensions in connection with EPRI's plume model validation project and the Salt River Project's visibility studies. Its sensitivity is such that it can readily detect plumes that are invisible to the unaided eye. The ALPHA-1 system was designed and built by SRI International and is presently operational on SRI's Queen Air aircraft. (RP1308, RP1616)

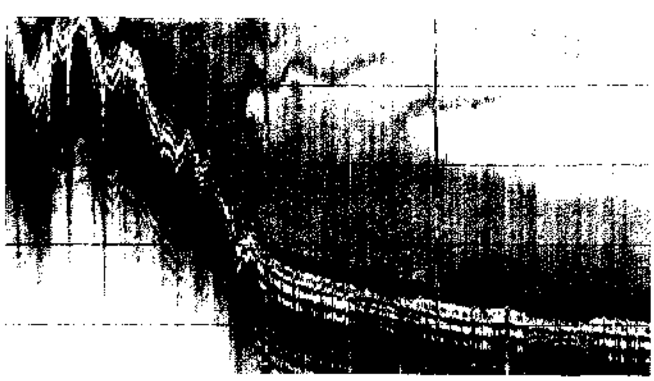
Waste Disposal Manuals

Coal ash, scrubber sludge, and PCBs are three utility industry waste products that require special disposal attention. PCBs, used to insulate capacitors and transformers, are highly toxic, and federal regulations stipulate their careful disposal. Ash and sludge from coal-fired power plants are also subject to increasingly stringent disposal regulations. Because proper disposal of ash, sludge, and PCBs can be costly, EPRI has published a series of disposal manuals for all three wastes. These manuals provide utility engineers with a sound basis on which to make economical and environmentally acceptable disposal decisions.



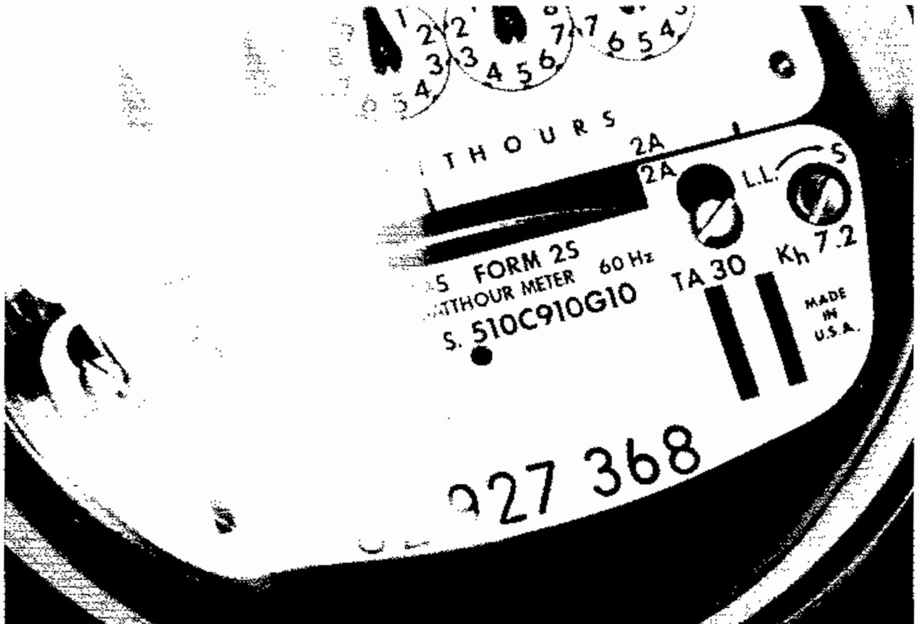
Installation of fabric filters at Emissions Control and Test Facility, Arapahoe station.

Turbine missile test at Sandia National Laboratories.

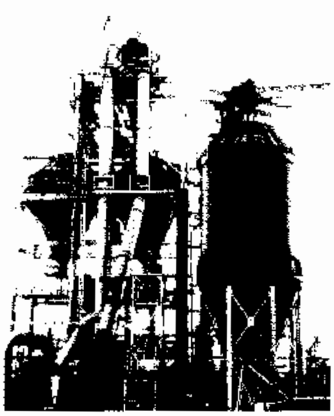


Lidar measurement of aerosol layer over earth's surface.

A watthour meter—focus of increasing energy awareness.



The coal liquefaction pilot plant for the H-Coal process, Catlettsburg, Kentucky.



NSAC project group at work.

For example, the ash manual includes data and procedures for developing disposal cost estimates and a quantitative procedure for evaluating environmental effects. The manuals are available through Research Reports Center. (RP1263, RP1685)

Rate Design Study

Consumers, regulators, and utilities alike seek means to slow the rise in electricity prices. EPRI's Rate Design Study has completed six years of research into load management, which includes time-of-use pricing and direct load controls. The sheer volume of information culled from the research makes it difficult for regulators and utilities to assimilate the research findings. For this reason, summary topic papers are being written and will be distributed early in 1981. In addition, technical transfer activities have been developed. In May 1980, regional conferences were held in San Francisco, Kansas City, and Washington, D.C. In April 1981, a set of regional workshops will be held to provide utility and regulatory staffs an opportunity to calculate costs and rates with the methods developed in the Rate Design Study. (RP434)

Nuclear Safety Studies

In its second year of operation, the Nuclear Safety Analysis Center (NSAC) picked up momentum in its work to help ensure that nuclear power plants are safe. NSAC has continued its probe of the Three Mile Island accident, including study of a number of theoretical alternative event sequences and their likely outcomes. A major conclusion was the high probability that the TMI-2 unit could have survived a core meltdown and reactor vessel failure with no more release of radioactivity outside the plant than actually occurred.

An important NSAC accomplishment has been the program to evaluate plant malfunctions, identify the significant items, and analyze and classify them. Notices and brief descriptions of the significant events are flashed by computerized telecommunication systems to all utilities having nuclear plants. Utilities are now quickly aware of significant events in other plants that might be precursors to damaging occurrences in their own plants.

In 1980 NSAC and Duke Power Co. launched a probabilistic risk assessment (PRA) project. The accident at Three Mile Island and studies since then indicate that abnormal nuclear plant operating conditions can develop from low-probability failures in plant equipment or from unusual operating situations. PRA is a method for predicting failure experience and the probabilities of various consequences. The effort will provide important input to the PRA guidebook being prepared as a joint industry and Nuclear Regulatory Commission undertaking.

An important effort for NSAC has been its work on a safety parameter display system, that is, a display panel that groups all the principal indicators of the reactor's operating state. It is expected that such a compact display will facilitate rapid and sound decision making by the operator in the event of an abnormal situation.

In 1980 Electricité de France, that country's national utility, and three Swedish utilities joined NSAC's U.S. supporting members. Negotiations with utilities in three other countries were near conclusion as the year ended.

Coal Liquids

Coal liquefaction processes yield liquid fuels that could provide electric utilities with a substitute for petroleum-derived fuels. These fuels are expected to have consistent quality, competitive prices, and environmental acceptability. EPRI, DOE, and private industry supported the construction of two large coal liquefaction pilot plants, which were completed in early 1980. One plant (Catlettsburg, Kentucky) will use the H-Coal process, a direct catalytic technique. This plant will process 250 t/d of coal to produce distillate oil and 600 t/d for heavy boiler oil. The other plant (Baytown, Texas) will use the Exxon Donor Solvent process. There, 250 t/d of coal will yield distillate fuel. Initial startup operations for both plants were completed in the last quarter of 1980. Sustained operations are planned to begin in early 1981. (RP238, RP778)

Reliability Prediction

A methodology and a model for performing reliability and availability assessments and predictions were completed in 1980 and applied to several power-generating systems. The model was developed by the ARINC Research Corp. of Annapolis, Maryland, with assistance from Fluor Engineers and Constructors, Inc., and EPRI. The model has been used to predict the reliability and availability of a proposed coal gasification–combined-cycle plant and to test the effects of various configurations; the plant configuration likely to be selected would have an equivalent availability of 82%. A number of alternative configurations for the proposed Cool Water plant were also evaluated. The results of this analysis are being applied to final selection of the Cool Water configuration. Applications of the methodology to an analysis of the Heber geothermal plant are in progress, and applications to other types of plants are possible by modifying the model. (RP1461-1)

Coal Gasifier Test Runs

Four thousand tons of Illinois No. 6 coal were gasified during 25 days of operation in Ruhrchemie-Ruhrkohle's technical version of the Texaco gasification demonstration plant at Oberhausen, West Germany. The objective of the tests was to obtain process performance and environmental data for scale-up of the 190-t/d gasifier to commercial size (1000 t/d) at Southern California Edison's Cool Water generating station near Barstow, California. In addition to meeting this objective, the tests demonstrated commercially acceptable refractory wear rates, rapid response of the gasifier to production rate changes, and the equipment's ability to operate satisfactorily at 50–120% of its rated output. (RP1799)

Looking Ahead: Some Expectations for the Next Five Years

CAS and UPH

Many utilities must use expensive power from oil-fired plants to meet peak demands. Some utilities now store less-expensive baseload energy by using pumped-hydro installations, but sites for such conventional surface reservoirs are becoming harder to find and license. Two promising new possibilities giving utilities a broader choice of options are compressed-air storage (CAS) and underground pumped hydro (UPH). In 1980 comprehensive studies funded by EPRI and DOE were conducted by engineering teams led by Middle South Services, Inc. (for CAS in salt caverns) and by Potomac Electric Power Co. (for both CAS and UPH in hard rock). Preliminary designs were developed and methodologies established for site selection, system studies, and preferred turbomachinery components and configurations. Study results confirm the near-term technical and economic viability of the CAS and UPH concepts and provide the basis for utility decisions on these new energy storage options. (RP1081-1)

NDE Center

Extensive research is under way to improve the nondestructive examination (NDE) techniques used to detect potentially troublesome materials flaws in nuclear power plants. But research is not enough—utilities need field-ready equipment and procedures, as well as trained technicians to carry out these examinations. EPRI's NDE Center at University Research Park, Charlotte, North Carolina, should fill that need. The staff at the recently opened center will quantify the performance of inspection systems; modify prototype systems for field use; evaluate inspection systems on full-size plant components; and develop the performance data bases necessary for realistic inspection requirements. The center will also train technicians to use the new equipment and procedures. Much of this training will consist of applying NDE techniques to full-size mockups, components, or specimens with service-induced defects. (RP1570-2)

On-Line Monitoring

On-line diagnostic systems for fossil fuel power plant components could alert utilities to incipient failures and thus lead to reductions in forced and scheduled outages. EPRI has recently concluded a long-term monitoring effort at New England Power Service Co.'s Brayton Point plant. Vibration and acoustic emission sensors were connected to a computerized monitoring system, thereby acquiring a data base of operation signals for a wide range of equipment. With vibration signature analysis, EPRI successfully tracked incipient failures of pumps, fans, and compressors. Beginning this year, the technology will be adapted for a utility industry predictive maintenance system. Another effort will use acoustic emissions to monitor boiler and feedwater heater tube leaks. New diagnostic systems will also be developed for turbine blade vibration, bearing and shaft failures, and other failure conditions. (RP734, RP1266)

DASS and PSMS

Recent NRC regulations require that computer systems to support operator decisions must be installed in nuclear power plants. One such system being jointly developed by EPRI, DOE, Commonwealth Edison Co., Duke Power Co., and other utilities is the disturbance analysis and surveillance system (DASS). This system can provide early diagnosis of power plant disturbances and guidance for corrective action. The scope and feasibility of such a system were recently established. Another system being developed to help operators is EPRI's prototype power shape monitoring system (PSMS), which can accurately monitor the status of a BWR core, as well as predict how it will respond to planned load maneuvers. The system is now being tested at Jersey Central Power & Light Co.'s Oyster Creek BWR. A second-generation system will be available to utilities in early 1981, and a large number of BWR owners have expressed interest in it. (RP891, RP895, RP1442)

Underground Cable Follower

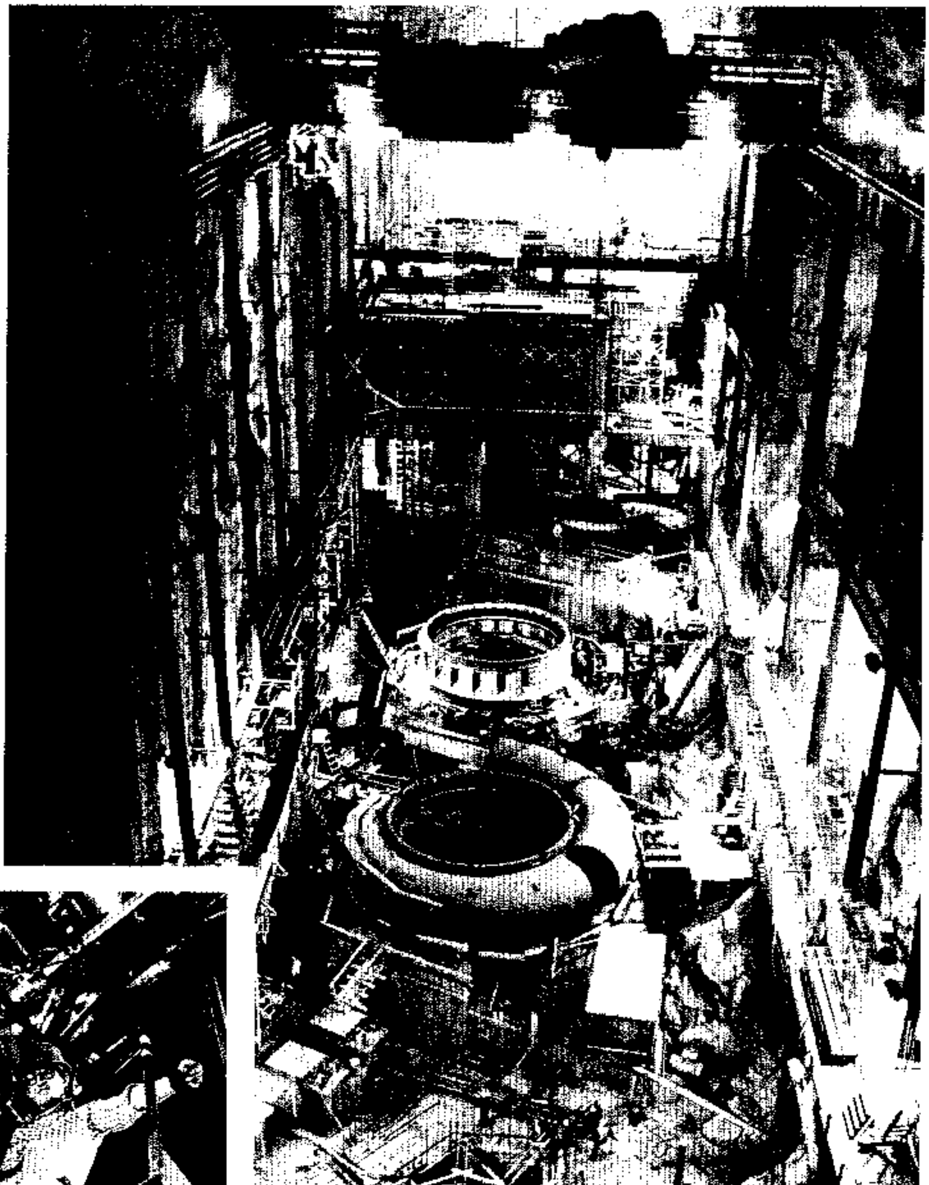
The failure rate of underground residential distribution cables is rising. Existing methods of replacing cables are expensive and often result in the disturbance of residential landscaping. EPRI is now developing a prototype steerable boring device that produces a 3–6-in horizontal borehole up to 1000 ft long. Under the same contract with Flow Industries, Inc., another prototype device, a cable follower, is being developed to actually replace failed cable. It requires excavation only at the start and stop points. Use of the failed cable as a guide makes it self-steering. It is also small, portable, and self-advancing, using the same power equipment as the boring device. It will be field-tested in early 1981. After debugging and additional field-testing in summer 1981, it is expected to be manufactured commercially. (RP1287)

Fluidized-Bed Combustion

By 1990 atmospheric fluidized-bed combustion (AFBC) may provide self-contained emissions control, increased reliability, and greater fuel flexibility to the utility industry. The AFBC boiler contains a bed of coal and limestone fluidized by air. Limestone absorbs the SO_2 formed during combustion. Relatively low bed temperatures resulting from improved heat transfer reduce NO_x formation and eliminate slagging. EPRI's 6-by-6-ft, 2-MW(e) AFBC development facility, situated at Babcock & Wilcox Co.'s Alliance (Ohio) Research Center, completed some 6500 hours of tests by the end of 1980; test results and design studies show AFBC can meet industry requirements, including combustion efficiencies, sulfur capture, and NO_x suppression. A 20-MW (e) engineering prototype, under construction at TVA, will be completed by early 1982 and will be used to test hardware and designs developed from the 6-by-6 facility under utility operating requirements. (RP718)

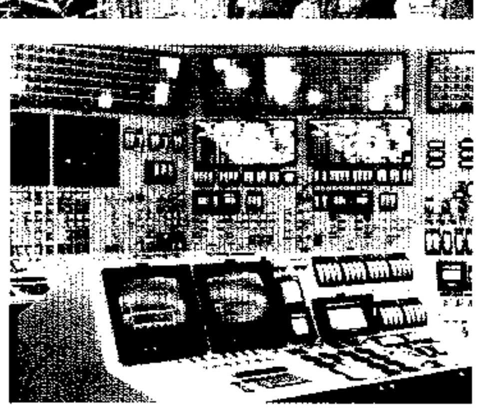
Dual Energy Use

Dual energy use systems (DEUS) are a means of using more of the energy in a fuel. For instance, when a utility generates electricity, some of the thermal energy rejected by power plants could be used for district heating; conversely, when an industry burns fuel for process heat, electricity could be generated



Underground powerhouse construction for Northeast Utilities Service Co.'s Northfield Mountain project. This is a conventional pumped-storage project, but UPH construction would be similar.

The 6-by-6-ft AFBC pilot plant at Babcock & Wilcox's Alliance (Ohio) Research Center.

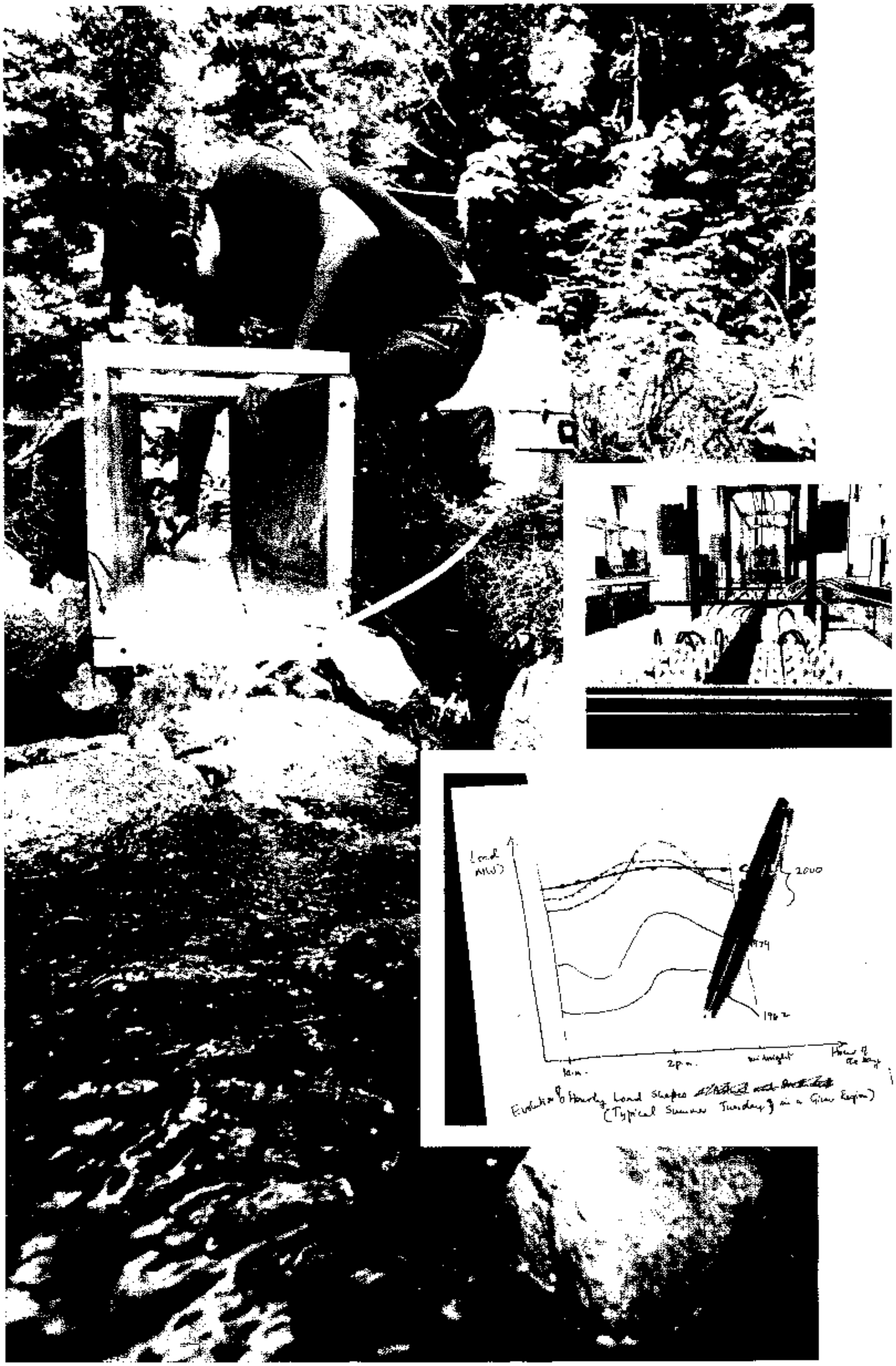


A standard nuclear unit power plant system (SNUPPS) simulator provided valuable input for DASS development.

Study of watershed acidification in Adirondack region, New York.

A 1.8-MWh lead-acid battery for testing equipment at the BEST Facility.

Sketch of hourly load shapes (high, base, and low cases) on a typical summer weekday in a given region.



as well. While substantial DEUS research, development, and demonstration activities are under way, dual energy use in a changing energy environment remains a complex issue, and more information on its technical, economic, and institutional aspects needs to be developed. In 1980 EPRI concluded baseline surveys of industrial cogeneration and district heating. The surveys identified the operating practices, characteristics, and problems of existing DEUS. Building on that information, EPRI is developing a methodology for assessing DEUS potential from both utility and industry perspectives. (RP1276)

BEST Facility

To be dedicated in April 1981, the Battery Energy Storage Test (BEST) Facility in New Jersey is nearly ready to begin the evaluation of advanced batteries developed for utility energy storage. A zinc chloride unit from Energy Development Associates will be the first in a planned 10-year test series of candidate units. The $17 million BEST Facility has taken shape under the joint sponsorship of EPRI, DOE, and Public Service Electric & Gas Co. (PSE&G), with the utility acting as prime contractor and host for the research program. Operating costs will be shared equally by EPRI and DOE. Battery modules of 1–10-MWh storage capacity rating will be evaluated in the facility, which is connected to the PSE&G grid. These modules will be representative of future 100-MWh battery designs that are expected to provide energy storage service for electric utilities in the late 1980s and beyond. (RP255, RP226)

Load Shape Forecasting

Utilities need to generate long-range load shape forecasts to plan capacity levels and generation-mix configurations. Two mathematical models have been developed that can provide and explain future patterns of hourly loads in 32 regions of the United States. In both models the hourly load shapes are analyzed in two stages. In the first stage, the effects of lifestyle and weather on loads are identified (e.g., day of the week and hour of the day; cloud cover and windspeed). In the second stage, the effects of economic, sociodemographic, and appliance-stock variables on hourly loads are modeled. A follow-on project will extend this research in two directions: greater detail on end-use loads and on utility service area characteristics. The contractors are Data Resources, Inc., and Quantitative Economic Research, Inc. (RP1008, RP1955)

Coal Gasification Power Plant Demonstration

Bechtel Power Corp. and General Electric Co. have recently become major participants in a 100-MW coal gasification–combined-cycle demonstration project, to be located at Southern California Edison's Cool Water site in Daggett, California. With the previous commitments from Texaco, Southern California Edison, and EPRI, this brings the total funding to $150 million of the $300 million total project cost. Negotiations are in progress with Pacific Gas and Electric Co., DOE, and an overseas consortium for their anticipated participation in the project. The plant design is well advanced, and suppliers of all major components have been identified. The participants plan to initiate procurement of equipment in early 1981, begin construction in July 1981, and start up the plant in October 1983. (RP1459)

Lake Watershed Acidification

A quantitative relationship is being developed between the deposition of atmospheric acids and the response of surface waters. Data collection began in late 1977 in three watersheds in the New York Adirondacks, each of which has a lake that responds differently to similar atmospheric inputs, indicating that biogeochemical processes affect lake acidity. A mathematical model has been developed that simulates these processes. Data collection is scheduled to end by late 1981 and final synthesis by late 1982. Analysis of data has led to the hypothesis that the characteristic hydrology of the watersheds and the process of mineral weathering are the two dominant factors governing the behavior of the lakes. Future plans include testing the validity of the model in other locations. Contractors include Tetra Tech, Inc., the universities of Virginia, Maine, Cornell, and Colgate, Smith College, and Brookhaven National Laboratory. (RP1109-5)

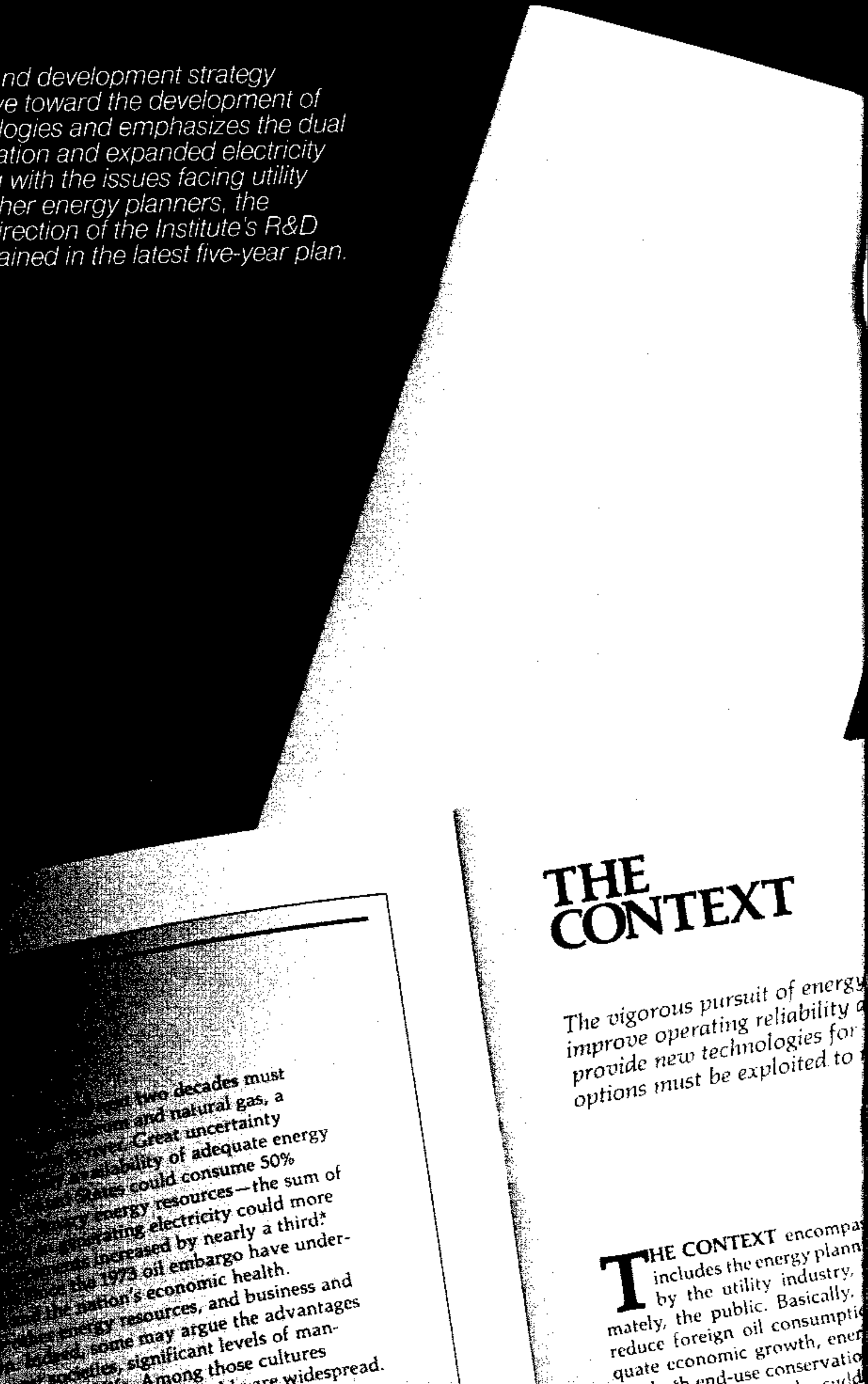
Geothermal Demonstration Plant

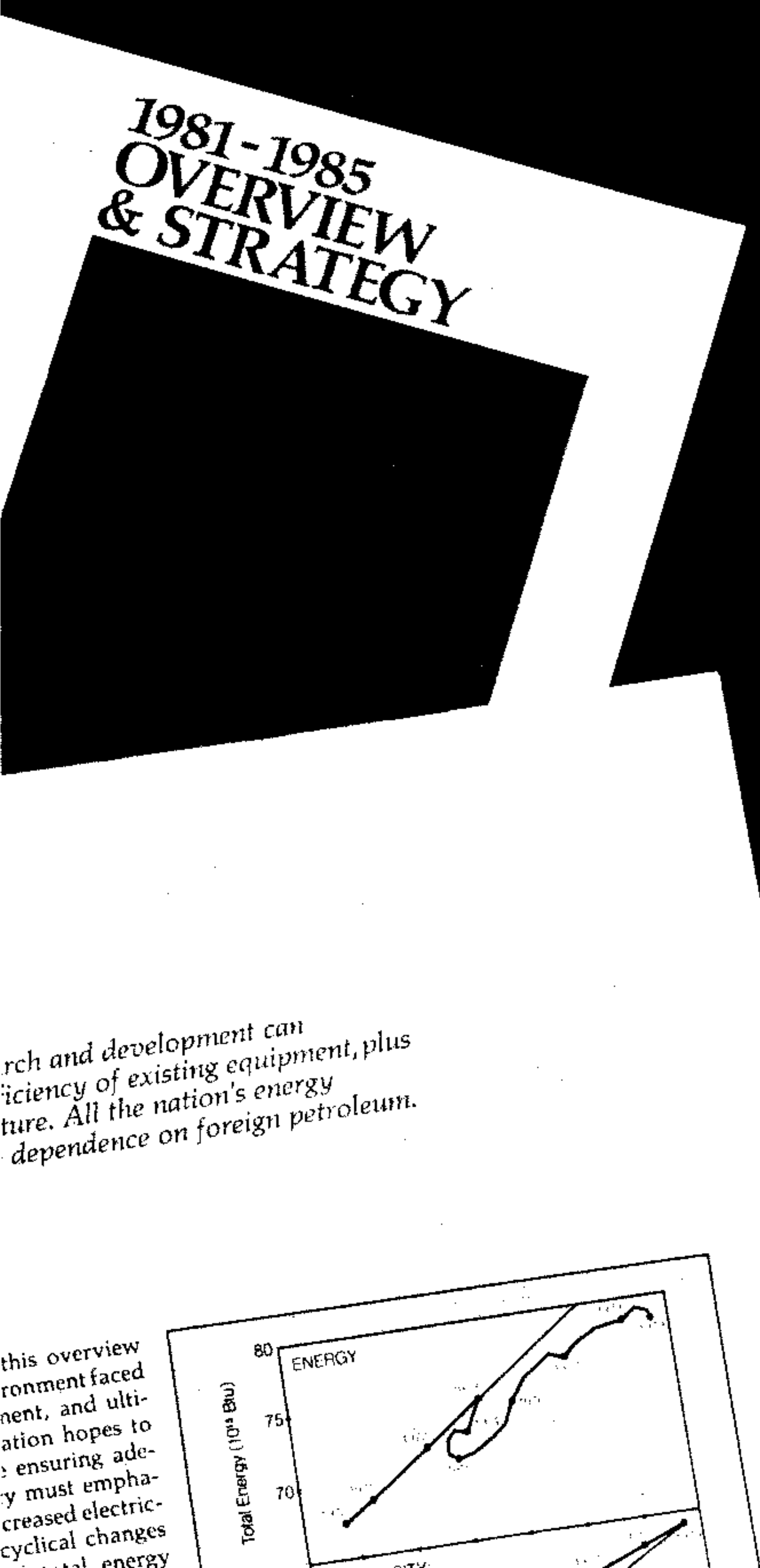
EPRI and the San Diego Gas & Electric Co. (SDG&E) recently signed a participation agreement to proceed with the design and construction of a 50-MW binary-cycle geothermal demonstration power plant near Heber, California. The project will be cofunded by EPRI, DOE, and a group of southern California utilities, with SDG&E as project manager for the sponsors. Construction is scheduled for completion in 1984 and will be followed by a two-year demonstration period. The purpose of the project is to demonstrate the commercial viability of binary-cycle technology as a way to develop natural hot water resources of moderate temperature and salinity. This technology should be commercially available to the industry in 1986 and is expected to provide the engineering basis for geothermal development beyond that date. The main advantage to the utility industry will be an alternative approach for geothermal development, nearly doubling the electric power potential from identified geothermal resources. (RP1900-1)

Obstacle Detector

Utilities need to plot an optimal route for cables before trenching streets and intersections. To this end, EPRI and Ohio State University have developed and are testing equipment for detecting, identifying, and mapping underground obstacles. The detection system sends radar pulses into the ground via a transmitting antenna. The pulses are reflected by the underground obstacle back to the surface of the ground and are detected by a receiving antenna. The received pulses are then processed by a computer that displays and prints a map showing the location, size, shape, and depth of the underground obstacle. The radar and computer system are installed in a van and are connected electrically to the antennas, which are mounted on a handcart that an operator pushes along the streets. (RP7856)

EPRI's research and development strategy continues to evolve toward the development of near-term technologies and emphasizes the dual needs of conservation and expanded electricity supply. Beginning with the issues facing utility executives and other energy planners, the framework and direction of the Institute's R&D activities are contained in the latest five-year plan.





National energy outlook for the next two decades must be viewed with concern. Great uncertainty exists over future economic growth and the timely availability of adequate energy supplies.

A recent EPRI planning document, *Overview and Strategy: 1981–1985 Research and Development Plan,* reviews these factors and describes the Institute's plan for research.

Beginning with the planning context facing utility executives and other decision makers, the document emphasizes the twin needs for greater conservation and expanded electricity supply. The Institute's response to national energy needs is outlined. And a timetable is presented, giving estimated commercial availability targets for EPRI-sponsored R&D efforts.

When EPRI was founded in 1972, the common perception was that most programs would be directed toward future options, systems, and technologies that could be of value around the turn of the century. Today, however, with increasingly urgent energy pressures, EPRI's focus has shifted to projects with a potential payoff in the next 10 years. About half of EPRI's R&D funds are allocated to this transition period research. About 40% of the funds are earmarked for projects that will yield results over a 10–25-year timeframe, and 10% are devoted to exploratory projects expected to pay off beyond the next quarter century.

The quandary

The question facing the United States and other industrialized nations in the world is how to achieve continued economic growth in an era when the bonanza of low-cost petroleum and natural gas is over.

National energy needs are related to the economic expectations of the people. Given expected increases in the size, age, experience, and education of the

American workforce, the U.S. economy needs to grow at least 2.5% a year to meet the minimum economic expectations of the people. Total energy use should grow by at least 1.3% a year to support this economic growth. This means that by 2000 the United States could consume 50% more energy than it does now.

Meanwhile, the percentage of total energy that goes into electricity production has been growing steadily—from 25% to 32% during the 1970s. Electricity has been increasingly substituted for other energy resources. By 2000, consumption of the resources used to generate power could more than double.

About one-third of our electricity generation now depends on oil and gas. But federal mandates are set to phase out natural gas and reduce oil use after 1990. For near- and mid-term power generation, coal and uranium provide a plentiful, domestically available resource. A central theme of EPRI programs, then, is full development of coal and nuclear power options. (The contribution of renewable sources, such as solar or geothermal electricity, is important but will still be limited by 2000.) Without such full development, the possibility of electricity shortfall is very real. Even with total generation from coal increasing 2½ times, roughly one-fourth of the nation's projected electricity needs will not be met at the century mark if nuclear development lags behind. Under these circumstances, nuclear power is not a question of preference but a matter of necessity.

The alternative is the likelihood of severe electricity shortages in some parts of the nation within the next two decades. Electricity rationing is unprecedented in the United States. But if failure to expand electricity supply brings us to that point, scheduled rolling brownouts and blackouts may be the only way to prevent even more serious and widespread outages.

The context

Three distinct economic growth projections underlie EPRI planning in 1980: low growth of 2.5% a year; intermediate growth of 2.9% a year; and historic growth of 3.5% a year. EPRI planning is based on the intermediate case, which is expected to include significant conservation—a 20% cut in the historic growth rate of electricity consumption. At the same time, prudent projections suggest that the utility industry should expect demand to grow from the present level of just under 2.4 trillion (10^{12}) kWh to 5.9 trillion by the year 2000. This means practicing conservation and expanding supply at the same time.

To hold down energy use without stunting economic growth, energy productivity of the industrial sector—the economic output per unit of energy consumed—must be improved. And the general economic climate must be sufficiently sound to encourage consumers to invest in new, energy-efficient appliances to replace their old ones.

Conservation measures linked to the intermediate growth target, for example, include improved insulation in 9 out of 10 of the nation's homes, passive solar heating in half of all new buildings, and an average of 28 mi/gal for all automobiles on the road (not just the newest).

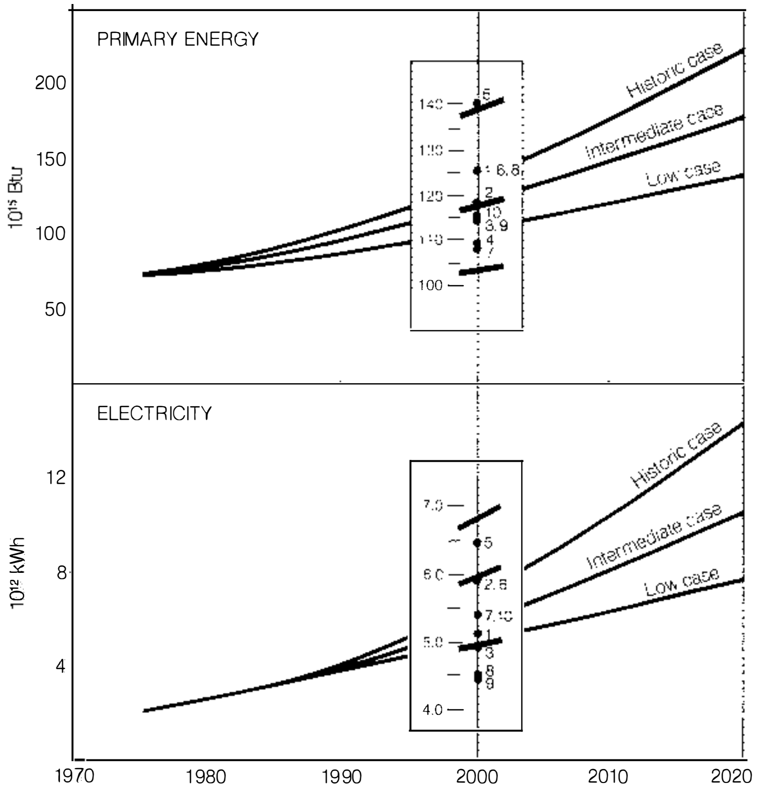
Energy conservation can also be achieved by reducing utility system losses. For example, one major utility calculates that reduction in transmission and distribution losses from 7.5% to 5% would be enough to supply electricity to a city the size of Oakland, California, or Louisville, Kentucky.

On the supply side, the amount of electricity we can use depends on two factors: installed generating capacity and the availability of primary fuels to run power plants. Generating unit availability has declined since the 1960s, and EPRI R&D is focusing major attention on this problem. Special emphasis is being devoted to reducing outages in large baseload plants, but efforts aimed at improved reliability extend to all aspects of system operation. More dependable transmission facilities, for example, minimize the possibility of widespread blackouts.

Fuel availability is the concern affecting supply. Coal and uranium will gradually have to replace oil and gas for power generation, but uranium supplies could be pinched as early as 1986–1987 if new mines are not opened. EPRI believes that development of the fast breeder reactor could extend the nation's uranium supplies an estimated 60 times, providing secure fuel supplies for nuclear energy in the foreseeable future.

As for coal, expanding production to nearly 2 billion (10^9) tons a year by the century's end will represent a difficult task. It means that coal producers will have to almost triple their output in less than 20 years. Labor-management problems, a shortage of both mining and supervisory personnel, and the disruptive boomtown effect triggered by rapid development of western and midwestern coal fields pose significant hurdles. In addition, the nation's railroad and barge systems will have to be upgraded and alternative transport methods explored if adequate capacity is to be available for carrying the increased volume of coal produced after 1990.

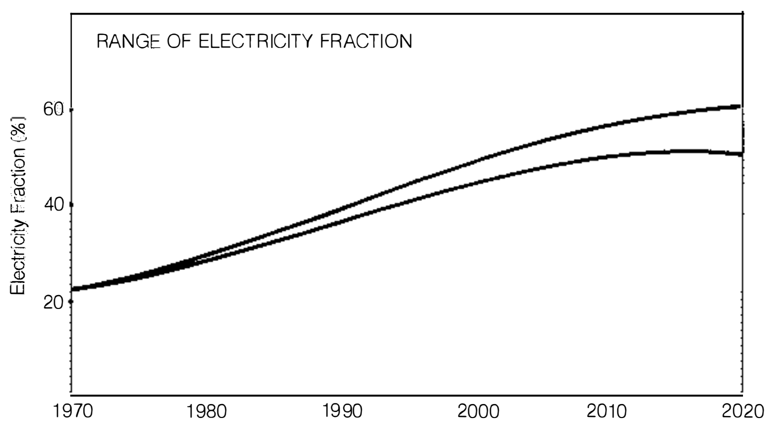
Historically, the electric utility industry has been able to supply increasing quantities of power at decreasing cost, thanks to technological innovation and economies of scale. But now the rising cost of money and the reluctance of inflation-wary investors to purchase long-term bond issues are creating serious problems in financing new capacity. In absolute terms, utility construction outlays will grow as electricity's share of total energy consumption increases. As a share of GNP, however, the nation's annual investment in electric utilities is expected to remain at about 1980 levels throughout this century.



1. EIA Vol. 3, 1979
2. Pilot, 1980
3. Westinghouse, 1980
4. Exxon, 1980
5. Hudson-Jorgensen, 1979
6. SRI World Energy Study 1979
7. EPRI Demand 80
8. CONAES Scenario III_3 1980
9. Resources for the Future, 1979
10. EEI, EGIF-II Preferred Case 1980

U.S. Primary Energy and Electricity Consumption
1979–2000 Average Annual Growth Rates

	GNP	Primary Energy	Electricity
Historic	3.5%	2.7%	5.2%
Intermediate	2.9%	2.0%	4.4%
Low	2.5%	1.3%	3.6%

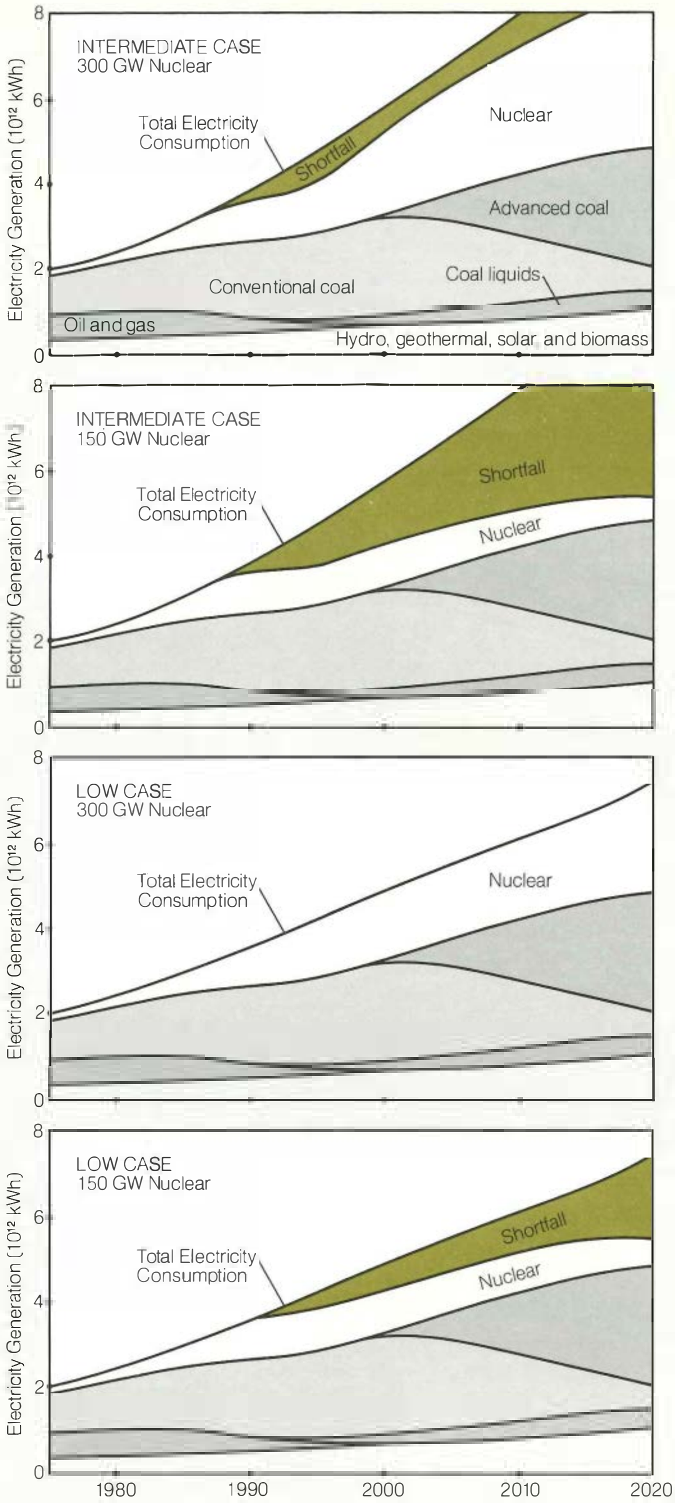


A KEY ASSUMPTION OF ENERGY PLANNERS: MODERATE ECONOMIC GROWTH THROUGH CENTURY'S END A prudent research and development program must be based on a range of economic projections. The top illustrations depict a range of energy and electricity usage and their relationship to the upper and lower boundaries of projected economic growth. In each case, the upper, or historic, curve represents a continuation of the 3.5 percent per year economic growth experienced between 1960 and 1970. It is unlikely that this high growth could be repeated in the foreseeable future. An intermediate 2.9 percent projection has been selected as the basis for EPRI R&D planning. A "zero expectation" economic growth rate (2.5 percent annually) is shown in the bottom curve. Vertical rectangles contain estimates obtained by other investigators for comparison with EPRI projections.

Electricity growth rates range from 3.6 to 5.2 percent through the year 2000, substantially higher than that for either primary energy or the economy as a whole. The intermediate economic growth case could require an average 4.5 percent yearly increase to provide the 5.9 million kWh by century's end.

The relatively consistent growth rates for electricity consumption reflect a decline in the use of oil and gas fuels. Moreover, electricity costs had been declining steadily prior to 1973, and even after the oil embargo, the national average real price increase has been relatively modest. For example, the national average price of electricity in constant dollars remained relatively constant in 1978 and 1979.

Electricity as a share of total energy has increased from 15 percent (1950) to over 30 percent (1980), a trend that is expected to continue.



THE FUTURE: A POSSIBILITY OF SHORTAGES IN ELECTRIC ENERGY Even with optimum development of coal, renewable resources, and expanded nuclear generation, an electricity shortfall is projected between the mid-1980s and the year 2000. The illustrations relate the size of the shortfall to "low" (2.5 percent) as well as intermediate (2.9 percent) annual economic growth, given different available levels of nuclear power.

Both projections reflect optimistic assumptions for development of coal and renewable resources: 100 GW contributed by hydroelectric sources; 10 GW by solar, biomass and wind energy; 16 GW by geothermal systems. Coal production is assumed to increase at yearly rate of 4.5 percent, allowing coal generating units to account for nearly half of installed capacity by century's end. The use of coal-derived liquid fuel for electricity generation is projected to reach 1 million barrels per day in 2000, at the same time the use of natural gas and oil declines significantly after 1990.

The separate supply scenarios are based on a) completion of approximately the number of nuclear plants with construction permits (150 GW in 2000) and b) hypothetical increase of nuclear capacity to 300 GW by 2000. In each case during the next twenty years nuclear power is the key swing fuel making up the difference between coal, gas and oil, renewables, and electricity requirements. Intermediate economic growth would require a nuclear expansion of greater than 300 GW in 2000. Even the low economic growth case requires greater than 150 GW of nuclear power capacity in 2000. If nuclear power is not expanded, imported oil and gas become the only alternative to a shortfall because coal is being developed at the maximum rate. These projected shortfalls likely will be felt in some combination of reduced economic activity substitution of more costly oil and natural gas energy resources, and more extreme conservation measures.

About half of EPRI's budget is devoted to environmental, health, and safety issues. Successful environmental R&D can significantly reduce the cost of environmental controls to utilities and consumers. Improved control technologies currently being developed for use at pulverized-coal plants, for example, could reduce by more than 20% the spending required to comply with air, solid-waste, noise, and water quality regulations. Other current topics of investigation include acid rain, the effect of air pollutants on visibility, and the potential toxicity of emissions from coal-fired power plants.

The context for EPRI's energy planning, then, is one in which simultaneous emphasis must be placed on several areas: the need for conservation, the need for expanded energy supplies, and the need to protect the nation's health and environment.

The response

To EPRI planners, the required response seems relatively clear. Aggressive conservation measures must be implemented. Research must be pursued that ensures efficient operation of existing equipment, as well as timely development of new technologies. Issues inhibiting expanded use of coal must be resolved. And a renewed national commitment must be made to the safe development of nuclear power.

Nine major premises guide EPRI's planning in response to current and anticipated energy needs.

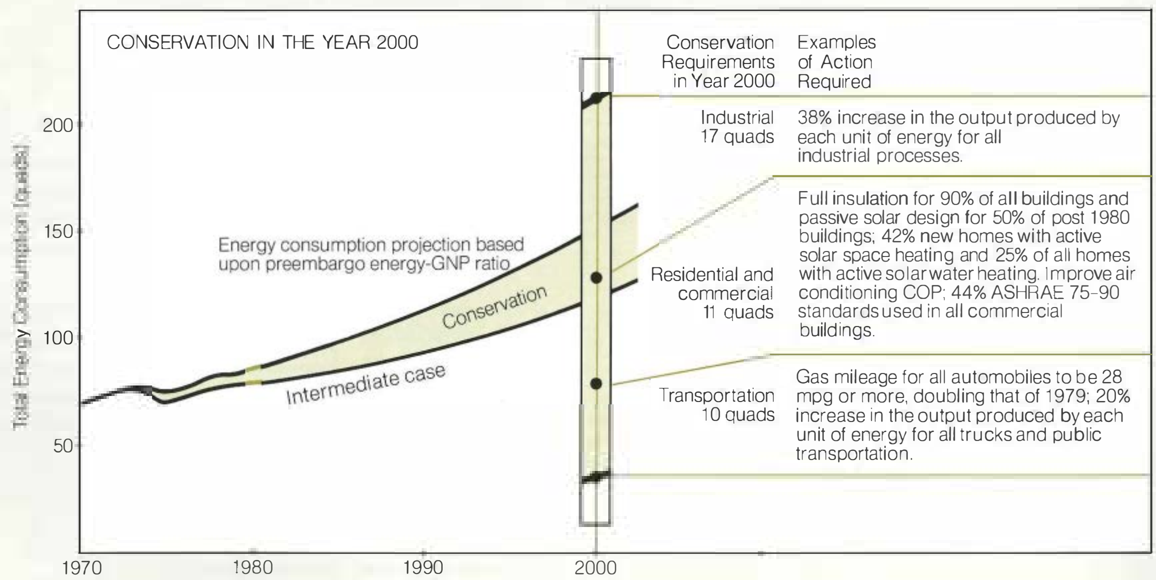
Energy and Society Electricity production in the United States must be sufficient to satisfy public expectations for individual economic growth.

As already mentioned, the availability of energy in general and electricity in particular is intimately tied to economic growth, which in turn is linked to living standards. Only twice during the current century—during the 1930s depression and during the 1974–1975 postembargo recession—has the growth in GNP failed to provide the minimum expectation in real income. Sufficient electricity must be made available to satisfy the aspirations inherent and necessary in an incentive economy.

Conservation and Supply Increasing constraints on the construction and operation of energy production facilities underscore the need for efficient energy use.

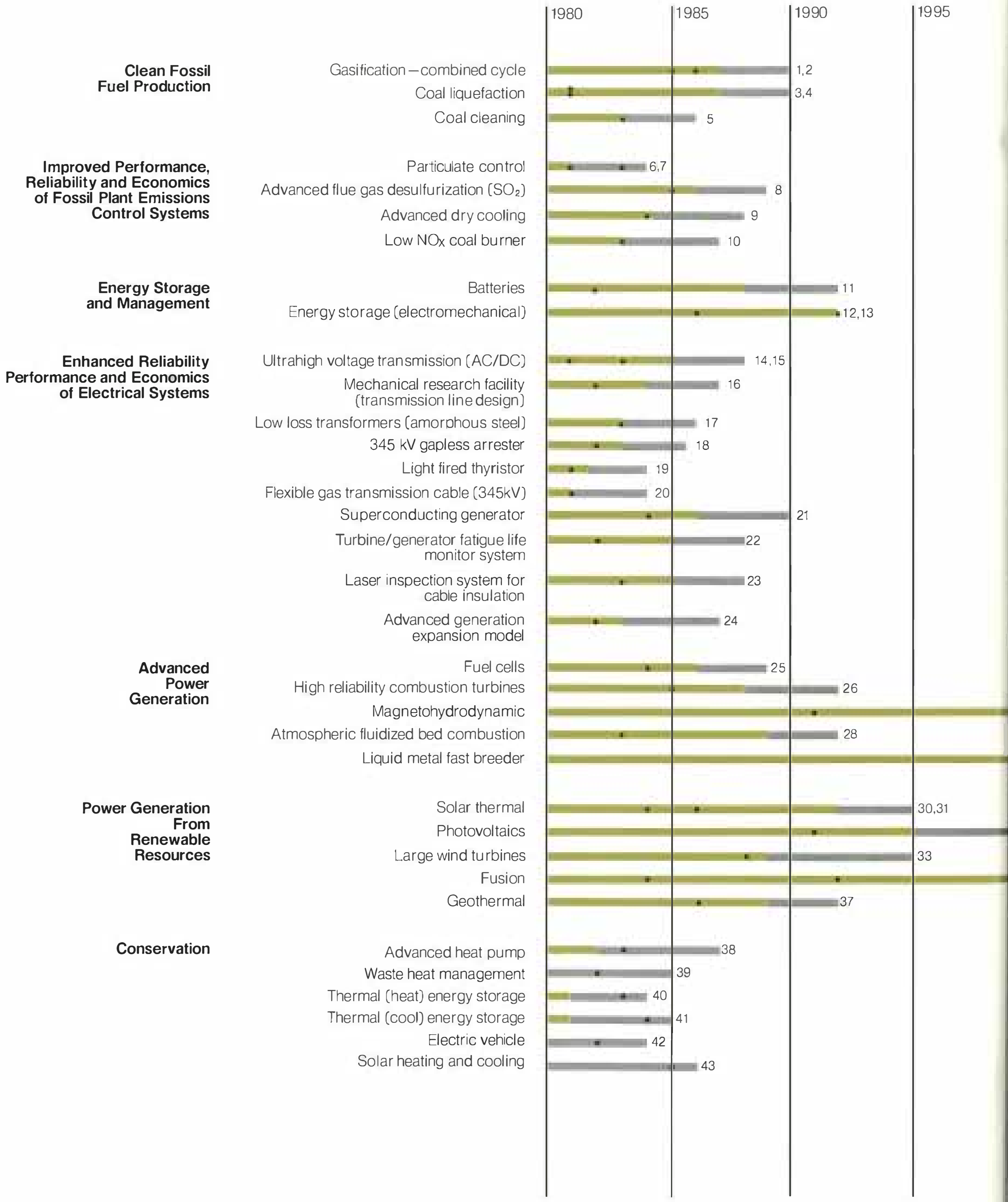
EPRI programs emphasize efficient generation technologies that can increase electricity supply; cost-effective methods to boost productive end use of energy; and improvements in utility system efficiency, especially in reducing transmission losses.

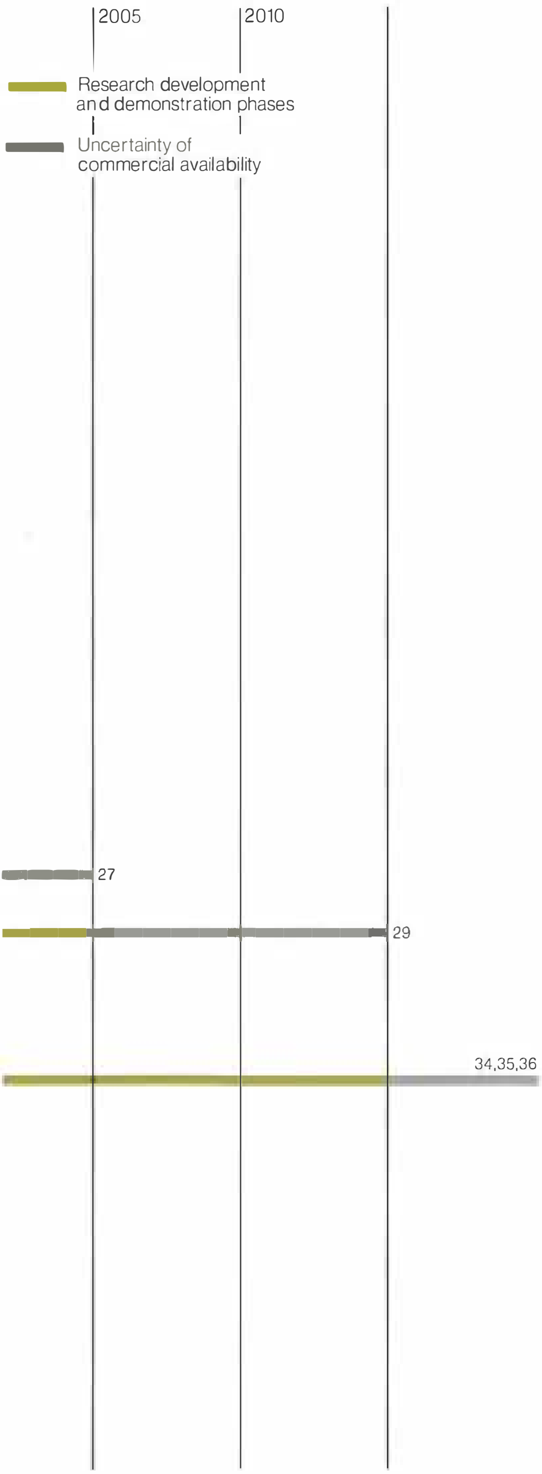
EPRI estimates that more-efficient electricity use by all types of consumers



WHAT CONSERVATION COULD REQUIRE IN THE YEAR 2000 An intermediate economic growth rate of 2.9 percent annually will require stepped up conservation efforts through the end of the century and beyond. The upper curve represents U.S. energy requirements had pre-oil embargo consumption patterns continued. A difference of 38 quads exists between these requirements and the energy projected as necessary to sustain intermediate economic growth in the year 2000. This analysis also reveals the significant conservation progress the nation has made since 1973. In 1979 alone, energy savings totalled an impressive four quads.

TIME LINE FOR RESEARCH RESULTS





THE TIMETABLE EPRI research is designed to yield outcomes in two broad categories: technologies that improve existing electric power systems and those that promise new and efficient options for meeting future demand. Typical examples of specific research results in the first category include: decay prevention in wood power poles; advanced methods of sulfur and particulate emission control in coal-fired power plants; and improved substitute materials and welding techniques to eliminate pipe cracking problems in nuclear reactors.

This illustration deals primarily with the second category of research, reflecting a continuum of key events in the development of long term projects. The culmination of each project is reached when it becomes commercially available, the date when utilities may begin placing equipment orders. Gray portions of lines reflect uncertainties in the timing of the date of availability. Licensing and construction times must be added to dates shown.

1 **Operate** 1000 Ton/Day Texaco Gasification Combined-Cycle Plant at Cool Water
2 **Operate** 150-MW Combustion Engineering Gasifier Integrated with Boiler
3 **Complete** 250 Ton/Day H-Coal Pilot Plant Tests
4 **Complete** Test Program at Exxon Donor Solvent 250 Ton/Day Pilot Plant
5 **Complete** Coal Cleaning Process Feasibility Verification and Process Optimization
6 **Issue** Guidelines for Design Optimization and Start-Up Procedures for Baghouse Systems
7 **Complete** Prototype Demonstration of Fine Particulate Agglomerator for Electrostatic Precipitators
8 **Complete** Demonstrations of Advanced Limestone Scrubber Processes
9 **Complete** Testing of Dry Cooling with Ammonia. Phase-Change Intermediate Loop and Conventional, Low Back-Pressure Turbine
10 **Complete** Prototype Demonstration of Low-NO_x Coal Combustion Technology
11 **Test** One Candidate Advanced Battery System at 10MWh Scale in BEST Facility
12 **Operate** Compressed-Air Storage Plant
13 **Operate** First Commercial Underground Pumped Hydro-Storage Plant
14 **Complete** Research on Corona Phenomena, Insulation Requirements, and Electric Fields
15 **Optimize** Design, Construction, and Maintenance Criteria for 1500-KV Transmission Circuits
16 **Begin** Construction of Mechanical Research Facility
17 **Establish** Commercially Acceptable Amorphous Core Steel for Transformers
18 **Complete** Field Test of 345-KV Gapless Arresters for Gas Insulated Substations
19 **Complete** Field Test of Light-Fired Thyristor in a Static VAR Generator
20 **Complete** Installation at Waltz Mill of 362-KV Prototype Flexible Gas Cable
21 **Complete** Initial Test on a Prototype 300-MVA Superconducting Generator
22 **Complete** Development of Torsional Fatigue Life Analysis Methods
23 **Complete** Demonstration of an On-Line Laser Device to Monitor the Quality of Solid Dielectric Cable As It Is Manufactured
24 **Complete** Methods for Analyzing the Effects of Load Management on Generation Expansion
25 **Fabricate** Second-Generation Fuel Cell Demonstration Module
26 **Begin** Full-Scale Tests of High-Reliability, Fuel-Flexible Combustion Turbine Test Engine
27 **DOE** Completes Pilot-Scale MHD Engineering Test Facility and Initiates Test Program
28 **Operate** 20-MW AFBC Facility at a Utility Site
29 **Operate** a 1000-MWe Prototype
30 **Complete** 10-MW Central Receiver Rankine-Cycle Pilot Plant and Initiate Test Program (DOE)
31 **Construct** 10-MW Brayton-Cycle Central Receiver Pilot Plant and Complete Checkout
32 **Complete** Development of Photovoltaic System with Installed Cost of $1000–$1300/Peak KW in 1980 Dollars (DOE Projection)
33 **100th** 2.5-MW Wind Turbine Generator Installed under Federal Program
34 **Achieve** Reactor-Grade Plasma
35 **Operate** Engineering Test Facility
36 **Operate** Engineering Power Reactor
37 **Operate** Heber Hydrothermal Demonstration Plant
38 **Complete** Validation of Advanced, High Efficiency Heat Pump
39 **Complete** Handbook on Waste Heat Recovery Applications for Restaurant and Food Industry
40 **Complete** Validation of Four Heat Storage Technologies
41 **Complete** Validation of Commercial Cool Storage
42 **Complete** Testing and Evaluation of 15 Electric Vehicles in Conjunction with Utilities
43 **Complete** Residential and Commercial SHAC Demonstration

could reduce electric energy demand some 20% by the year 2000. Accordingly, it is sponsoring development of advanced heat pumps and energy audit programs for consumers. From the standpoint of total-system savings, cogeneration and other emerging technologies offer further possibilities. Cogeneration, for example, can salvage the otherwise wasted heat produced in conjunction with generating electricity for nearby factories, homes, and businesses.

Financial Requirements Because of continuing inflation and high money costs, utilities are faced with serious financial constraints in meeting future electricity demand.

EPRI programs emphasize R&D that can help utilities reduce current and projected increases in spending and revenue needs. By 1985, for example, a 1% reduction in outage rates at coal and nuclear plants could save $1.5 billion ($10^9$); a 1% improvement in output efficiency (heat rate) could save $2 billion; and a 1% reduction in transmission and distribution system losses could save $1.1 billion (all in constant 1979 dollars).

Reduced Dependence on Foreign Fossil Fuels National security considerations, balance-of-payment deficits, and the unreliable supply of imported oil and gas render dependence on foreign fuel sources both unwise and dangerous.

EPRI emphasizes both supply and end-use approaches to reducing consumption of oil and gas as boiler fuels. On the supply side, load management and energy storage programs can help shift the burden of electricity production away from oil- and gas-fired units and toward baseload units fueled with domestic coal and uranium. Likewise, the improved desulfurization technologies that EPRI is working on can be expected to enhance the efficient use of domestic coal resources.

From the standpoint of demand or end use, anything that helps the consumer use less oil and gas contributes to the goal. Electric vehicles, for example, could save 145 million barrels of gasoline yearly, assuming 12 million such vehicles are operating by the century's end. Other EPRI-sponsored efforts focus on actual development of energy-saving hardware, such as advanced heat pumps.

Coal and Uranium Coal, coal-derived synthetic fuels, and uranium must supply the backbone of electricity generation for at least the next two or three decades.

A major theme of the EPRI programs is the development of coal and nuclear power for baseload electricity generation. EPRI is a major participant in programs to develop clean gaseous, liquid, and solid fuels from coal. Indeed, spending for the Institute's fluidized combustion and clean gaseous fuels research is scheduled to increase by one-third over the next three years.

In the area of coal-derived gas, EPRI is contributing $50 million to the construction of a gasification–combined-cycle demonstration plant to be built near Barstow, California, this year. In its Clean Liquid and Solid Fuels Program, EPRI is pursuing three candidate processes based on reacting coal with hydrogen: the H-Coal process, designed to yield heavy liquid boiler fuels and distillates for peaking turbines; the Exxon Donor Solvent process, designed to produce light turbine fuels; and the SRC-I process, designed to produce clean solid fuels. All three processes now have pilot plants in operation.

But even with expanded coal generation, more nuclear power must be provided if the nation is to meet minimal generation needs without expanding oil imports. In addition to conducting research aimed at improving plant efficiency and reliability, EPRI hopes to shorten lead times by providing safety-related information that utilities can use to expedite plant approval and licensing. Current projects in this area include relief valve testing, loss-of-coolant and earthquake analyses, containment missile evaluations, and probabilistic safety analyses.

New Resource Technologies Decades may be required for a new form of electricity generation to contribute significantly to the nation's energy needs. Development of new resource alternatives for the next century, therefore, should begin now.

EPRI is working on both solar-thermal electric power (the power tower concept) and photovoltaic cells that can convert sunlight directly to electricity. The emphasis of its solar hardware research is on the development of higher-efficiency concentration devices for the first option and lower-cost, thin-film substitutes for the silicon coating used on cells in the second.

Active assessment of wind energy conversion is also under way, with government and private support. And EPRI is helping to develop a demonstration plant to generate electricity from geothermal hot water at Heber, California. EPRI is also conducting research that complements DOE's effort to explore the potential of fusion power. EPRI's work on fusion is directed toward the operational aspects of fusion reactors—ways to make their operation economic and environmentally acceptable.

Current Technologies Until new technologies become available, major emphasis must be placed on the economic, reliable, and environmentally acceptable production and delivery of electricity from presently available technologies. The EPRI strategy emphasizes developments with potential benefits for utility systems during the next 10–20 years. Improvements in existing coal and nuclear plants are therefore a key part of EPRI's program.

Many current power plants that were designed for baseload operation on high-quality fuels are now being called upon to operate under cyclic load conditions, using more-abundant, lower-quality fuels. This means a special research effort must be made to cope with new conditions. For example, tubing failures (caused by transition welds of dissimilar metals, as well as by embrittlement and corrosion) account for about 50% of all operating time losses in fossil fuel boilers. Current research on this and on blade failure in power turbines is expected to help large coal-fired plants perform reliably despite changing load patterns and fuel quality, a payoff that could increase effective plant capacity in such units by up to 3%.

Present nuclear plants are also the focus of reliability-boosting R&D. Assuring pressure vessel and piping integrity with minimum outage costs is one target. Another is to minimize the occurrence of denting, pitting, and cracking in steam generator tubes, which can also be costly both in dollars and in outage time.

Environment Improved knowledge of the ecological impact of utility operations can help establish better-understood and more-effective standards. Research covers the health effects of air and water effluents, electromagnetic fields, and solid wastes and their disposal. A concurrent program concentrates on developing cost-effective technologies.

Important projects now under way include regional sulfate monitoring, as well as studies of the impact of thermal power plant cooling systems on aquatic environments. Possible beneficial uses of the by-products of electricity generation are also being reviewed: the use of waste heat for agriculture and aquaculture, constructive use of fly ash and scrubber sludge, and the recreational/wildlife benefits of cooling-tower reservoirs.

Human health effects are also being studied, particularly in connection with coal combustion. In an effort to help utilities find cost-effective ways to comply with air quality standards designed to protect human health, EPRI is working on the demonstration of advanced fine-particulate and nitrogen oxide control technologies (by 1981); demonstration of a cost-effective scrubber for removing sulfur dioxide from stack gases at existing coal-burning plants (by 1982); and demonstration of an atmospheric pressure, fluidized-bed boiler plant capable of sulfur and nitrogen oxide removal with minimal postcombustion control devices (by 1984). Improving air quality control devices could reduce the anticipated cost penalty of tighter post-1985 standards by an estimated 50% or more.

Facility Siting Power plant siting and utility rights-of-way acquisition are critical utility needs, yet both confront greater difficulties as competition for available land, water, and air increases. Economic, social, and institutional factors will play an increasing role in facility location.

In response, EPRI strategy emphasizes the development of technologies that will require less land for generating plants; require less water consumption than current systems; permit use of seawater cooling; and permit siting in areas with rigid air quality standards. For example, desulfurization-recovery processes can lessen land requirements for solid-waste disposal. Ultrahigh voltage, dc, and underground transmission technologies reduce land areas needed for electricity delivery. And various solar energy forms—wind, photovoltaics, and hybrid solar-fossil plants, for instance—require substantially less water than does conventional generation.

The commitment

The nine premises just outlined form the framework for EPRI's response to national energy issues. They also form a framework of broad R&D goals that eventually find expression in specific programs. Especially noteworthy is the fact that the specific programs mentioned here and in the accompanying time line span quite a broad range.

In covering so wide an area, these programs reflect the basic commitment behind EPRI planning: a commitment to the belief that resolution of our energy quandary will depend on the nation's willingness to employ all its energy options. The issue is not a choice of conservation *or* coal *or* nuclear *or* renewable resources; rather it is our readiness to use conservation *and* coal *and* nuclear *and* renewable resources. We do not enjoy the luxury of selecting among these alternatives. To preserve what we now have and move ahead, we must use all of them.

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