Part 3: A Strategic Plan for the 21st Century—
Industry Reports on its Contributions to Energy Education

This report concludes the series of articles developed by Dr. James Winebrake, Assistant Professor in the Integrated Science and Technology Program at James Madison University. His objective—to outline a method for collaboration between academe, the government, and industry in order to raise energy education to much higher efficiencies—may seem visionary. But already, a mutually beneficial interaction is in the first stages of development. Three representatives of different segments of industry describes how cooperative efforts presently underway are moving along Dr. Winebrake's trajectory.

Integrative Problem-Solving: The Basis of Modern R&D

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INTRODUCTION

Professor James J. Winebrake argues compellingly the need for well-rounded, technological problem-solvers capable of integrating aspects of many disciplines into their expertise. He calls for an "integrated science and technology" curriculum that reflects the very real and urgent changes we in technology-driven industries like electric power currently face.

From its inception more than a century ago, the electric power industry has been shaped by technological innovation. And innovations have often come from the unexpected convergence of seemingly disparate fields. But today, an unprecedented number of disciplines are represented in the generation, delivery, and use of electric power—from electrical and chemical engineering to nuclear physics, computer sciences, telecommunications, regulatory policy, business planning, and econom-

ics. The emergence of environmental issues like global climate change, which now shape many of the decisions utilities make, has added substantially to the range of disciplines that successful utilities must now master in their day-to-day operations.

The trend toward multidisciplinary expertise in our industry, as in many others, is certain to intensify. Competitive business conditions have created increased demand for collaborative initiatives that bring together a wide range of players, often from very different industries and representing a spectrum of scientific fields. At the same time, the prospects for tomorrow's advances are more and more likely to be found in technology fusion—the productive and often unexpected convergence of very different lines of research. Most important of all, solutions to the complex environmental and energy problems we face are increasingly holistic in nature, addressing the interaction of many different parts of highly complex systems in an integrated whole. Companies must participate in a global trade of ideas and innovations in order to compete successfully. We're really in the business of *knowledge* innovation, after all, as some analysts have put it—the nurturing and development of new ideas that create new markets, new opportunities, new competitive options.

Together, these emerging business and research trends have intensified the need for individuals who can integrate technical and scientific knowledge with experience and training in business planning, public policy, government, and a wide range of fields.

That's a tough challenge. The sheer volume of knowledge is said to be doubling about every seven years—particularly in technical fields. Half of what students learn in their first year of college is obsolete by the time they graduate. The pace of change is just as dizzying for technical experts at any stage in a career. By training "professional generalists," as Dr. Winebrake proposes, colleges and universities will help equip individuals with the ability to remain responsive to the rapidly accelerating pace of change.

What kind of world will college graduates of today enter? Part II of this paper will look at the changing nature of technological solutions in industry. Part III will explore how global competition and changing government and business priorities are shaping the future of science and technology research. Part IV will look at the changing face of R&D, particularly the kind of collaborative initiatives that the Electric Power Research Institute (EPRI) has pioneered.

THE NATURE OF TECHNOLOGICAL SOLUTIONS IS CHANGING

The Need for Holistic Approaches

Twenty years ago, environmental issues tended to be addressed on the local or regional level. Increasingly we've come to understand that both energy and environmental effects have an impact on complex systems and require holistic approaches—solutions that take into account many different fields of expertise.

The best example is global climate change. Determining whether there is indeed a risk, and quantifying exactly what the nature of that risk might be, requires work in far-reaching disciplines, from advanced computer modeling and climate studies to emissions control technologies and health effects research. We need to understand not only the nature of today's power plants and the potential effects of man-made emissions but also how natural systems such as the ocean and the atmosphere interact dynamically.

But that's just the beginning. Mitigation measures must be assessed for both cost and benefit, an enormously complex task that brings together chemists and climate scientists, electrical engineers and economists. And because this is a global issue, we need to integrate into our solutions knowledge about the specific conditions of individual countries, including their economic situation and stage of technological development. The most enlightened efforts of a single nation or even a group of nations, after all, will have little impact without an international consensus and strategy. As research and policy-making evolves, we will need individuals who can bring these diverse pieces together to formulate coherent holistic approaches.

The same is true even when we're addressing regional or national environmental issues. Air toxics, for instance—trace elements emitted by power plants—have recently come under increasing regulatory scrutiny in the US. A rational response not only requires understanding the extent of the emissions and their potential health threat—research that embraces a variety of diverse fields—but also requires developing cost-effective control measures. And because we are dealing with not only scientists and policy-makers but the public, we need people who can communicate complex scientific and technical issues directly and convincingly.

At EPRI, we've seen the convergence of fields reflected in our own program. Originally we organized our R&D by specific technical areas,

analogous to college courses. More recently we've reorganized the Institute's work into more than 80 "targets," each of which may bring several disciplines to bear on finding solutions to specific industry challenges. Moreover, we now offer a variety of joint targets—R&D that bridges several distinct fields of technology or science. We've created Community Technology Solutions teams, for instance, to support sustainable community growth and development through improvements in infrastructure. The aims include improved energy efficiency, environmental quality, and disaster-resilient solutions. By its nature, the work requires scientific generalists with knowledge of specific technologies as well as broad community needs.

A Greater Emphasis on Technology Fusion

The nature of technological solutions is also changing. In the past, the path toward technological innovation typically lay in discoveries within a single field. The more we could master within a particular discipline, the more insight led to innovation.

But we've begun to see a very different trajectory toward innovation—not a single line but rather multiple lines of research, often in very different fields, that suddenly and often unexpectedly converge to create breakthroughs. The big R&D leaps of the future, many analysts agree, will come not from incremental advances but from the fusion of very different technologies to create wholly new innovations.

In the 1960s and 1970s, for instance, NASA developed advanced imaging technologies for the space program. Now petroleum geologists are using the same techniques to locate oil reserves underground. (The data they supply has helped our industry better estimate oil and gas reserves and plan long-term energy strategy.)

The electric power industry has benefited from technology fusion in other ways. In the 1970s, the aerospace industry developed new turbine technologies for jet engines that took advantage of insights into both engineering design and new materials technology. General Electric took up the result and developed advanced combustion turbines which today offer tremendous environmental and cost benefits as a means of generating electricity.

More recently, the convergence of advances in computer systems and telecommunications has led to something few of us envisioned 10 years ago: the Internet, a truly global communications network that is creating linkages that are only just beginning to reveal the range of pos-

sible applications. Some companies now base their entire business strategy on the Internet, which is revolutionizing not only communications but information and product distribution in many industries.

Technology fusion is, by its nature, collaborative. The challenge is to have people with the breadth of training and expertise to serve as a bridge for collaboration, to recognize the promise of new advances in a wide range of fields, and to explore ways to apply them in very different kinds of applications. Beyond that, we need an overarching structure for R&D that allows key players to exchange information and insights and to synthesize very different perspectives, ideas, ways of doing things that are much more powerful than any one company can come up with.

The Need for Targeted Technology Scanning Capability

The accelerating pace of scientific and technical development is challenging. Advances occur fast—often in fields of study outside an industry's focus, increasing the need for experts to bridge diverse disciplines and identify, via technology scanning, important developments that can be imported. In fields as diverse as biology, software design, materials science, and chemistry, new knowledge is gathered so rapidly that many industries scramble to create in-house technology scanning capability: a way to quickly identify promising developments.

To anticipate longer-term advances, the electric power industry supports a program of strategic R&D. Part of that effort is what we call "future watch"—providing utilities with current information on future technical, business, and social trends that could affect the use of electricity and the structure of the U.S. utility industry in the future. Also, we're conducting and monitoring exploratory research in emerging areas of science and technology that could radically alter the course of the electricity enterprise—including high-temperature superconducting wires and the application of neural network and fuzzy logic approaches to advanced control systems to generation and deliver electricity.

At the same time, to take stock of nearer-term development with immediate practical applications, EPRI produces technical assessment guides that integrate the Institute's experience and expertise in multiple scientific and technical disciplines to provide members with a single-source assessment of key new technologies, including current and emerging generating and storage technologies, as well as distributed generating options such as solar, small combustion engines, and fuel cells. These assessment guides are now being offered in formats that can

provide customized cost and performance information based on specific individual operating conditions.

SCIENCE AND TECHNOLOGY ARE NOW GLOBAL ENTERPRISES

The Blurring of Industry Lines

Driven in part by technology fusion, the past decade has seen another trend: the blurring of industry lines. Not long ago, the telecommunications, computer, and electric power industries seemed distinct enterprises; today they're starting to merge in ways only beginning to be understood. For instance, EPRI recently entered into a joint development agreement with the Oracle Corporation, an information management leader, to develop a networked computer that will use the Internet to allow utilities to provide a wide array of new energy services, such as home automation, real-time pricing, and appliance monitoring capabilities. That initiative brings together experts in software design, information and telecommunications systems, manufacturers, and marketing in a completely new mix.

Similar examples abound. At first glance, an Institute devoted to energy R&D might seem to have little connection to the field of medical care. But in fact, EPRI has pioneered the development of innovative microwave technology that offers a more efficient and effective way to decontaminate medical waste. We recently began testing an ultraviolet device installed in air filtration systems that can dramatically slow the spread of tuberculosis. To recognize the potential of such integrated systems, we need researchers and program managers who can see beyond the narrow confines of a single discipline.

The Rise of Global R&D

Just as the borders between industries have begun to fall, so too the geographic boundaries for both research and competition are falling as advances in telecommunications put every part of the globe in touch with every other part. To stay abreast of developments in rapidly evolving fields, US experts must now collaborate with scientists in many other nations. As a result, networks of international affiliations are springing up to hasten progress in many fields. EPRI, for instance, recently signed a ground-breaking agreement with the Polish Power Grid Company to work together. The agreement will help Poland create an advanced

transmission and distribution system efficiently and cost-effectively. And because the agreement specifically involves technical institutes and universities throughout Poland, it enables our researchers and utilities to expand their network of expertise.

The same trend is around the world. In Europe, for example, there's Eureka, a collaborative R&D program aimed to create strategic collaborative partnerships among its 24 member nations. In France, the National Center for Telecommunications Studies (CNET), the research arm of state-owned France Telecom, has been forging international alliances with other telecommunications research centers, including Italy's Center of Studies in Telecommunications Research (CSELT), Japan's IT Labs, and British Telecom Labs. Canada has created the National Research Council's Industrial Research Assistance Program, which promotes collaboration between small manufacturers and scientific and engineering expertise in government labs, universities, and research centers.

The rise of international networks and affiliations adds yet another level of complexity to the work we do. As we're learning at EPRI, the rise of global R&D initiatives has created new demand for professional generalists in fields such as international law, public policy, intellectual property rights, and business.

THE NATURE OF COMPETITION AND COLLABORATIVE R&D IS CHANGING

Need to Justify R&D at the Bottom Line

The 20th century has seen unprecedented technological and scientific progress. We live longer, healthier, more productive lives than ever before. So it seems ironic that, over the past decade, as competitive pressures have intensified, both government and industry have reevaluated their commitment to R&D. Overall spending on basic research slowed dramatically in the 1990s. According to recent figures from the National Science Foundation and the Brookings Institution, industry spending on research and development has fallen significantly over the past decade. Competitive pressures have sharpened the focus on near-term results with identifiable bottom-line benefits. And, the commitment to basic research, which is risky and expensive by nature, has eroded significantly.

The same trend is altering the landscape of government-funded research. As recently as 15 years ago, it was accepted that manufacturers

would concentrate on research that was 1 to 5 years out. Most collaborative R&D organizations focused on projects with a horizon of 5 to 10 years. And the federal government took over responsibility for funding the longer-term work, the really exploratory, high-risk research.

That's rapidly changing. The federal government, under tremendous pressure to cut costs, is substantially downsizing its commitment to R&D. The American Academy for the Advancement of Science recently called these "the most significant across-the-board funding cuts to the research and development enterprise in the post-World War era." Even in industries that remain committed to R&D, there is a growing emphasis on the bottom line.

What will that mean for the R&D enterprise of the future? Intensifying competition means scientists and technologists will have to work more closely than ever with business planners. In that role, we must argue persuasively the benefits of what we do, and ensure that basic research finds its fullest value in practical applications. For that, we will need both specialists and generalists who can work closely with business strategists. Just as importantly, we will need leaders in business who have adequate grounding in the sciences to understand the potential benefits of basic R&D.

Change in R&D

At the same time, the structure of R&D must remain responsive to the changes in industry. In the electric power industry, we're seeing the emergence of dual-track programs that explicitly combine short-term solutions with longer-term R&D—a trend reflected in other industries, as well. Over the past decade, for instance, we've supported an aggressive program to create a new generation of solid-state electronic controllers to replace the mechanical switches that have traditionally been used to control the flow of electric power over the nation's complex grid. The resulting system, which we call a flexible AC Transmission system, or FACTS, has required a long-term vision and commitment. But at that same time, we've targeted near-term development programs that have yielded advanced equipment that has already been rapidly deployed to prove the benefits of FACTS and maintain support for longer-term research. Such dual-track programs are likely to become more central to R&D in an increasingly competitive environment.

In order to fund necessary research and development, many companies and R&D labs are forging new alliances with manufacturers, gov-

ernment agencies, environmental groups and others. Such alliances have already brought together unlikely partners. Fierce competitors have joined in targeted collaborative ventures in the race to develop flat panel displays to replace conventional cathode ray television screens and computer monitors, for instance. In the intensely competitive field of consumer photographic products, a handful of major companies, all head-to-head competitors—Kodak, Fuji, Nikon, Canon and Minolta—agreed several years ago to an unprecedented collaboration. The goal was to develop a brand new generation of photographic systems based on advanced film and camera concepts that would jump start fresh growth in the industry.

We've seen the same unprecedented alliances in the electric power industry. Perhaps the most striking are those that have brought utilities together with public interest environmental groups to find solutions to specific environmental issues. In one example, researchers, biologists, advocacy groups, and the utility industry joined forces to examine whether power lines and lights threatened shore birds on the Hawaiian island of Kauai and to draft specific solutions that would protect these birds. In an even broader collaborative effort, several US utilities, along with the Nature Conservancy and a nongovernmental organization in Belize called Programme for Belize, have formed the Rio Bravo project. The goal is to voluntarily offset some of the utilities' emissions of carbon dioxide by conserving and managing a 120,000-acre tropical forest in Brazil.

Again, such alliances demand individuals with a broad range of experience and the ability to bridge both technological and policy areas, as well as scientifically trained generalists able to communicate the issues to the general public.

Miniconsortia Address the Need for Rapid Solutions

Traditionally, collaborative R&D efforts have been formed to address challenges larger than single players alone can manage. They have typically focused on long-term problems. But a new kind of collaboration is emerging, driven by the accelerating pace of technological change and the need for quick responses to urgent problems. These so-called miniconsortia are brought together to resolve a specific, narrowly delineated issue. They may exist for no more than a year or two and then disband.

Many miniconsortia are being established within the framework of larger R&D institutions, using the model of small entrepreneurial groups working within larger corporations. EPRI, for instance, has moved to-

ward a program that combines a broad portfolio of shared research with initiatives tailored to the needs of a small group of members—or in some cases, even a single member. The new model that's emerging can be represented by a pyramid. The base constitutes the research that all parties fund and whose results are shared by all. At the top are the narrowing layers that represent varying degrees of customized research and development.

The same layering is emerging at many other consortia. There's the traditional broad collaborative effort, in which many members fund a particular area and share in the results. Then there are arrangements in which members fund an area jointly and individual members follow-up with research of their own to shape the results to their specific needs.

The new model directly addresses the need for both competitive and collaborative R&D. But it also creates new levels of complexity in managing and carrying out research. The rise of miniconsortia has created new demand for individuals who can assemble a diverse team, establish a carefully defined agenda, and manage highly technical work in a short period of time. The skills required include not only technical know-how but management capabilities such as team-building, strategic planning, and technology transfer. And because these alliances must move quickly or be left behind, they demand experts already up-to-speed in several related disciplines who can integrate the efforts of this new form of consortia.

CONCLUSION

Intensifying competition has sparked a debate over the future of collaborative R&D. The question is simple. Do competitors have any reason to collaborate? The answer that is emerging is yes. Even in highly competitive marketplaces, the evidence shows, there are many examples of productive collaboration. Why? What we're learning is that targeted collaboration designed to advance an entire industry or open up whole new markets benefit all the players. So in the end, intensifying competition is likely to build support for collaborative R&D. And that, in turn, will increase the demand for scientific generalists—individuals with a strong grounding in science and a range of knowledge that allows them to work in a variety of fields.

ABOUT THE AUTHOR

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Mr. Rudman, who had been serving as EPRI's senior vice president of corporate services, rejoined EPRI in 1989 after two years as president and chief operating officer of Aster Publishing, a publisher of eight scientific business trade magazines. He originally joined EPRI in 1973 as assistant to the president, held increasingly responsible positions, and in 1983 became vice president of EPRI's industry relations and information services. His contributions in the past include creating a member services organization, developing technology transfer assistance for member utilities, upgrading the Institute's computer system to meet rapidly growing information needs, and leading the development of EPRI's Tailored Collaboration and Progressive Flexibility programs.

The author of numerous publications, Mr. Rudman holds a B.S. and M.S. in nuclear engineering from UCLA and has served on several technical and information exchange committees. In 1995, he was elected to serve as chair of the Council of Consortia, an organization of chief executive and senior officers from the nation's leading research and development and applied technology development consortia.

Developing A Long-Term Learning Strategy for Industry

Chuck Miles
Johnson Controls

In today's radically changing world, we are often asked to do more, faster, with less resources. The rapid change prevalent today, driven by the world around us, affects the competitiveness of our organization and causes us to look for new ways to perform our duties within that orga-