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Progress in Energy R&D

Our present pattern of energy utilization will someday be substantially altered. Impetus for change will arise from our inability to sustain continued increases in oil imports, or to mounting concerns about the greenhouse effect, acid rain, or urban pollution. Four articles in this issue of *Science* describe progress in developing technologies that may be helpful in responding to the next energy crisis.

Hubbard describes dramatic improvements in photovoltaic (PV) technology. Scores of new PV materials and many new designs have been explored. As a result, the cost of PV electricity has dropped from \$15 per kilowatt-hour to about \$0.30 per kilowatt-hour. To be competitive with future electric generations options, PV modules must exhibit solar energy efficiencies in excess of 15% at costs somewhere between \$0.06 and \$0.12 per kilowatt-hour. Recent striking improvements in efficiency of conversion of solar energy to electricity and continued improvements in methods of manufacture indicate that this goal may be attained by the mid-1990s. A competitive solar cell industry has emerged, and substantial research is being conducted in a number of countries.

Burnett and Ban describe ways in which prospects for natural gas have improved. The energy content of natural gas production in the lower 48 states is already substantially greater than that of oil, and research and development have shown that methane occurs and is recoverable in many places in which oil is not present. Examples include coal seams, shales, and deep formations. A recent U.S. Department of Energy reassessment of the resource base concluded that technically recoverable natural gas in the lower 48 states is 1059 trillion cubic feet—a greater than 50-year supply at today's usage.

Natural gas is a clean fuel that gives rise to much less pollution than either coal or oil. In applications for cogeneration of electricity and heat, thermal efficiencies of 60% to 80% are achieved. The authors describe other new applications that guarantee an increasing role for natural gas in the U.S. energy mix. For example, the use of small amounts of gas in coal-fired and waste-burning furnaces can lead to substantially decreased emission of pollutants. Improvements in furnaces for home heating have made gas highly competitive with oil or electricity.

Ross discusses energy efficiency in industry. He points out that largely in response to the energy shocks of the 1970s, U.S. manufacturers reduced their real fossil fuel intensity ratio of energy use to production by 50%. In the past decade there have been only sporadic improvements, and Ross states that the cost-effective opportunity now available is very large. In addition to potential financial advantages, the technology of efficient energy use is improving rapidly. Manufacturing is being revolutionized by introduction of new sensors coupled with electronic processing of information, followed by automatic control of processes. For example, equipment being installed in steel mills increases yields by controlling thicknesses during the rolling process. Another development in industry is use of electricity in new applications where special advantages are achieved. That is, electric heating processes can achieve extremely high energy densities. In arc plasmas temperatures of 10,000°C are routine. In almost every sector of industry pioneering methods of obtaining increased efficiency and energy savings are being implemented. If an energy crunch comes, these demonstrations will find energy-saving replications.

The history of nuclear energy in the United States is a striking illustration of how a great nation can flub a major technological development. Taylor states that the average capacity factor in the United States is about 60% as compared to 75% to 85% in some countries. In addition, U.S. operations and maintenance costs are averaging roughly twice what other countries spend. The U.S. utilities have now set goals to bring their average performance and cost effectiveness to a world competitive level while devoting top priority to safety. Designs of three different reactor systems are moving ahead with five goals in mind: (i) assured safety with features that minimize consequences of human error, (ii) a significantly simpler design, (iii) high reliability throughout a lifetime of on the order of 60 years, (iv) reduction in capital and other costs and a construction time of 3 to 5 years, and (v) a standard design that is predictably licensable.—PHILIP H. ABELSON