3 May 1985, Volume 228, Number 4699 **SCIENCE**

Evolving Patterns of Energy Production and Use

Many factors have combined to make profound changes in the energy picture. One consequence of the interplay of factors has been to decrease the vulnerability of the United States to an interruption of petroleum supplies. Imports of petroleum and its products into the United States are now about half of what they were in 1978. Another development has been a lessening in the ability of OPEC to control the prices of oil. Still another consequence is to place a lid on the cost of all forms of energy and hence a restraining force on inflation.

Factors contributing to these changes include a substantial increase in the efficiency of energy use which, coupled with conservation practices, has decreased demand for petroleum products. The trend toward improved efficiency of energy use continues and is likely to continue. Another development has been the installation of large numbers of oil-refining units capable of producing excellent yields of high-value products from heavy crude oils. This has enhanced the value and marketability of heavy crudes. Another development has been increasing discoveries and production of oil by countries outside OPEC, including Brazil, Colombia, Egypt, India, Mexico, Norway, Pakistan, Peru, and the United Kingdom. Another factor in easing the demand for oil has been the substitution of other energy sources such as natural gas, coal, and nuclear.

The enhanced value and marketability of heavy crudes is fostering increased production of them and is diminishing the premium paid for light, sweet crudes. The amount of crude oil required to produce a given quantity of refined products has decreased. Substantial production of petrochemicals is coming on stream in Saudi Arabia. This will result in diminished production of them in the United States, thereby lessening somewhat consumption of natural gas and crude petroleum here. Powerful computerized geophysical techniques are being applied to improve reservoir engineering. This in turn is also leading to enhanced oil recovery from known fields through use of such procedures as CO_2 and steam injection.

In the United States the discovery rate for natural gas has improved from what it was in the 1970's. At that time about twice as much was consumed each year as was found. In recent years additions to reserves have nearly balanced production. The present abundance of producible gas has led to a lowering of prices and competition with oil for use as a heat source. In turn, natural gas in encountering determined competition from electric power for industrial, commercial, and residential markets. One response by the gas industry has been to develop more efficient appliances so that gas can compete better with electricity. For example, the thermal efficiency of one line of burners for new home heaters has been increased from about 60 to 90 percent.

At present the use of coal as an energy source is the subject of environmental concerns about acid rain. But the lower cost per Btu and development of improved means of reducing sulfur emissions guarantee expansion of the use of coal. Fluidized bed combustion and gasification to produce clean intermediate-Btu gas are destined to have substantial future applications. Industrial use of fluidized beds has been expanding. High-ash, high-sulfur coal can be burned, and emissions of sulfur oxides and nitrogen oxides can be limited to practically any desired level.

An increasing share of the world's electricity is being generated at nuclear power stations. Leaders in this development are the United States, France, and Japan. In France and Japan, the use of nuclear energy diminishes imports of corresponding amounts of oil. Special circumstances in the United States have led to a poor climate for nuclear energy, but its use continues to expand.

Inevitably, domestic supplies of oil will diminish, but if current trends of increased energy efficiency and of substitution are maintained, transition to the use of other energy sources will proceed relatively smoothly.

—PHILIP H. ABELSON