technology, has a pipe-cross configuration in which liquid raw materials are mixed. This assembly is mounted within the granulator so that heat produced by the chemical reactions helps to form and dry the granules. With this design the final product has less than 1% moisture, in contrast with the 5% to 7% moisture content found in conventional fertilizers before drying. In addition to reducing or eliminating the drying operation, this technology yields a superior product and reduces pollution control problems.

Seven innovative reactors are now operating in the fertilizer industry, saving about 0.12 trillion Btus per year. Projected annual savings in 2010 are 5.4 trillion Btus.

Irrigation Systems

An estimated 60 million acres of agricultural land are irrigated in the United States, consuming nearly 270 trillion Btus annually at a cost of $1.4 billion. DOE, in cooperation with five universities and five private businesses, funded a program to develop and demonstrate new energy-saving technologies for irrigation. Three technologies resulting from the program have yielded significant energy and water savings. The new technologies are computerized scheduling, reduced-pressure application systems, and drop-tube application systems. Reduced-pressure sprinkler irrigation technology is used at about 15,000 sites across the country, and the three technologies together are saving about 4.3 trillion Btus annually. They could save 40 trillion Btus per year by 2010.

Oxygen Production by Chemical Air Separation

Industrial oxygen is used in many thermal processes at metal, chemical, and utility plants. Currently, it is produced by the cryogenic process in which air is compressed, liquefied, and distilled into its components. For this process, thermal energy must be converted to mechanical energy to compress the air, and about two-thirds of the thermal energy is lost during this conversion. Typically, about 2000 Btus are used to produce each pound of oxygen.

With DOE cost-sharing, Air Products and Chemicals is developing a continuous chemical separation process (known as MOLTOX) invented by the Energy Concepts Company. The process is based on the ability of some salts to absorb and release oxygen with changes in temperature and pressure. Because this process uses thermal energy directly and recovers energy from the exhaust air, it requires 40% less energy (when combined with a steam boiler) than current cryogenic processes. Thermal energy can be conveniently supplied from high-temperature plant waste heat. The chemical air separation process produces oxygen at 99.8% purity.

Potential applications include use in the steel, chemical, and electric utility industries. Operation of the process was demonstrated in a quarter-ton-per-day process development unit. Electricity consumption in the new process is also lower than in the conventional process, resulting in an overall energy savings of 44%. Annual savings in 2010 are estimated at 44.1 trillion Btus.

Carbon Dioxide Recovery from Industrial Waste Streams

The rapid expansion of enhanced oil recovery has resulted in a demand for carbon dioxide, which is used to make crude oil flow more readily. Currently, the only economical sources of carbon dioxide are natural deposits and process vents at hydrogen plants.

In cooperation with the Argonne National Laboratory, DOE has successfully completed a test to recover carbon dioxide from dilute waste streams from industrial furnaces. The process involves burning coal in an environment of oxygen and carbon dioxide rather than relying on the natural mixture of nitrogen and oxygen. The process uses 25% less energy than the conventional process and creates an effluent stream that is rich in carbon dioxide (about 95%). The process also eliminates the need for flue gas desulfurization and carbon dioxide purification.

The major costs of the coal-oxygen process are the capital costs of the air separation plant and the cost of the electricity required to run the plant. The capital cost of a separation plant is approximately $21,000 per ton per day for a plant with a daily capacity of 1818 tons. The electrical requirement is 242 kilowatt-hours per ton of gaseous oxygen produced. Production of a ton of carbon dioxide with the process requires 0.8 ton of oxygen.

Within a 300-mile radius, the recovered carbon dioxide can be transported to most oil fields at a total cost that would be competitive with other sources. It was estimated that enhanced oil recovery techniques could recover 50% of the reservoir potential by 2000