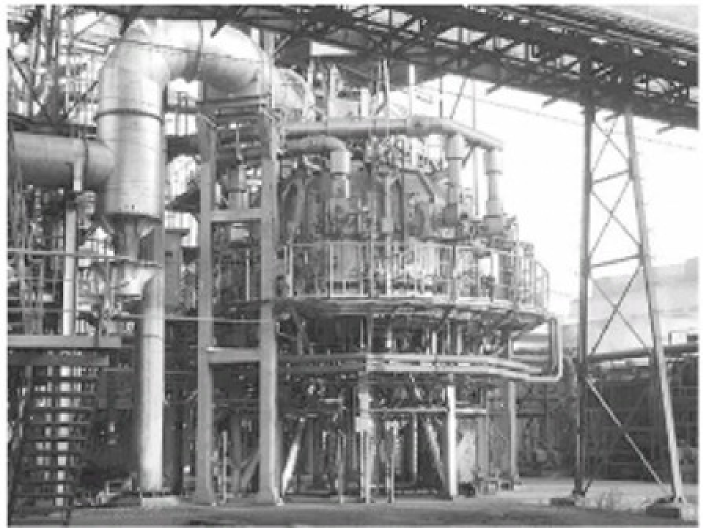
1.4.3 INDUSTRIAL PROCESS EFFICIENCY

Technology Description



A new one-step furnace operation could revolutionize iron making and substantially reduce energy use and associated emissions.

Industrial process efficiency is affected by a number of factors: technology design, age and sophistication of equipment, materials of construction, mechanical and chemical constraints, inadequate or overly complex designs, and external factors such as operating environment and maintenance and repair practices. In many cases, processes use a lot more energy than the theoretical minimum energy requirement. In the chemical industry, for example, distillation columns operate at efficiencies as low as 20-30%, and require substantially more energy than the theoretical minimum. In this case, thermodynamic and equipment limitations (e.g., height of the column) directly impact efficiency and increase energy use. Technologies under development focus on removing or reducing process inefficiencies, lowering energy consumption for heat and power, and reducing the associated greenhouse gas emissions. One example is a revolutionary steelmaking process that uses a one-step furnace operation to produce high-quality iron, using substantially less energy than conventional processes. The process under development eliminates the need for the coke oven plant, which is a significant source of emissions in steelmaking.

System Concepts

- Process efficiency is improved by optimizing individual processes, eliminating process steps, or substituting processes within the principal manufacturing steps for primary conversion of raw materials, secondary or value-added processing, and product separation. Optimizing the overall manufacturing chain also improves process efficiency, including the material and energy balance.

Representative Technologies

- Process redesign can eliminate energy-intensive process steps, as demonstrated by the one-step furnace operation under development for ironmaking. Smaller changes to a process can also result in increased process efficiency. For example, DOE is supporting research to modify steel-casting methods that will reduce energy use and produce cleaner, lower-weight castings of improved quality.
- Advanced separation technologies include membrane separation and pressure swing adsorption, where separation is facilitated by novel materials and is energy-efficient.
- Catalysts with higher selectivities enable the conversion of a larger fraction of the feedstock into the desired product rather than the less desirable byproduct. Lower byproduct generation also can positively impact the energy consumption of separation and purification technologies.
- Alternative processes involve developing a new route to the same product and can incorporate advanced separation technologies and new and improved catalysts. An example of this is the process currently under development to convert natural gas to acetic acid using a new biocatalyst.

Technology Status/Applications

- Components of more efficient processing technologies under development (e.g., membranes) are in limited use today, but many need stronger economics or technical viability to increase their attractiveness to industry. The biggest opportunities to reduce GHG emissions in industrial processing will come from introducing revolutionary technologies as replacements for conventional operations. Examples include direct steelmaking and use of membranes as substitutes for energy-intensive distillation separations. Other options include developing new processes that increase product yields, reduce byproducts and wastes, or use alternative manufacturing pathways.

Current Research, Development, and Demonstration

RD&D Goals

- Between 2002 and 2020, contribute to a 30% improvement in energy intensity by the energy-intensive industries through the development and implementation of new and improved processes, materials, and manufacturing practices.
- By 2010, in partnership with industry, assist efforts to implement advanced water-removal technologies in papermaking resulting in an energy efficiency improvement of 10% in paper production compared to conventional industry practices.
- By 2010, develop advanced aluminum production technologies, such as carbothermic reduction, noncarbon inert anodes, and wettable cathodes, for a 25%-30% energy reduction – and, in some cases, elimination of greenhouse gas emissions from primary production.
- By 2010, develop mining technologies that reduce the energy intensity required to crush a short ton of rock by 20%-30% (from 1998 baseline).
- By 2010, in partnership with industry, assist efforts to develop a commercially viable technology that will eliminate the use of energy-intensive coke as a feedstock in the steelmaking process.
- In partnership with industry, assist efforts to enable major technical advances in the metal-casting industry to implement new design techniques and practices, increase yield, and reduce scrap and energy use.
- In partnership with industry, assist efforts to develop separation and new process chemistry technologies that will increase energy efficiency by up to 30% by 2020, compared to conventional 1998 technologies: Develop advanced chemical reactors, including short contact-time reactors, reactors for nonthermal processes (plasma, microwave, photochemical), reactors for alternative media or dry processing, and flexible processing units; improve catalytic processes including selective oxidation, hydrocarbon activation, byproduct and waste minimization, stereo-selective synthesis, functional olefin polymerization, and alkylation.
- Develop advanced separations technology, including membrane separations (advanced inorganic membranes, ruggedized membranes, selective membranes, anti-fouling), reactive separations, and separative reactors for use across various industries (chemicals, refining, pulp and paper).
- In partnership with industry, assist efforts to reduce energy consumption in carburizing processes, heat treatment of castings, welding processes, and aluminum alloy-forging processes.

RD&D Challenges

- Specific R&D needs are unique to each individual industry. In general, R&D challenges include economic and innovative separation techniques, improved understanding and prediction of chemical and material behavior, materials fabrication methods, in situ and/or rapid analytical protocols and process screening procedures, advanced computational tools, and more efficient process design.

RD&D Activities

- RD&D activities relating to these technology areas are sponsored by DOE, the Department of Commerce, the Department of Defense, the National Science Foundation, and the Environmental Protection Agency. DOE has funded projects to improve energy efficiency and reduce waste; participants include industry, DOE laboratories, small businesses, and academia.
- Ongoing activities include development of technology to enable more efficient processes in the following industries: aluminum, chemicals, forest products, glass, steel, metal casting, mining, and supporting industries such as forging, welding, and others. The primary focus of R&D is the development of economic, energy-efficient, commercially viable, and environmentally sound manufacturing technology. Industrial partners are involved with R&D early on to facilitate deployment and commercialization.
- Michigan Technological University is leading a dozen industrial partners in developing a Total Ore Processing Integration and Management System. This novel system will allow mine and mill personnel to

respond rapidly to upstream and downstream changes to optimize the entire mineral processing stream, reducing mill and mine energy use by 10%.

Recent Progress

- Researchers have developed and tested a nozzle that generates a high-temperature, high-momentum oxygen jet, which provides superior mixing and combustion conditions for blast furnace coal injection in steelmaking. This technology enables increased coal injection into the furnace, allowing steelmakers to displace some of the coke typically used in blast furnaces with coal and thus reduce fugitive emissions associated with coke-making.
- A fiber-optic sensor for on-line measurement of paper basis weight has been developed and tested to improve wet-end control in papermaking and produce fine paper with more uniform basis weight. The sensor enables continuous measurements across the full paper sheet and will minimize raw material and energy requirements in the paper industry.
- DOE has supported the development of a portable gas-imaging device for an advanced leak-detection system designed for use in the petroleum and petrochemical industries. The portable gas leak detector reduces the amount of time required for leak surveys, enabling inspections to be performed more frequently than with current detection methods. Gas leaks can be identified and repaired more quickly, reducing emissions.

Commercialization and Deployment Activities

- Applications of many of the described technologies already have an impact in the marketplace. For example, catalytic processes are responsible for about 75% by value of all chemical and petroleum processing products. Catalytic processes generate about $900B in products annually. The ready acceptance of certain applications of these technologies reduces barriers to implementation of process improvements or their application in new processes. Powerful drivers still exist for implementing advancements in these technologies for GHG reduction. The estimated total annual consumption of energy (fuels and electricity) by the U.S. chemical process industries is 5.8 quads; nearly 43% of that (2.5 quads) is required for separation processes, including distillation, extraction, adsorption, crystallization, and membrane-based technologies. Any process facilitating such separations will result in enormous savings of both energy and waste. Given the scale of many relevant industrial processes, the chief barriers to technology deployment are likely to be the capital expenditures required for any substantial process modifications.

Market Context

- The markets for these technologies are industry-specific. Targets of opportunity are the basic industries, including aluminum, chemicals, forest products, glass, mining, steel, and crosscutting industries such as forging, metal-casting, and welding.