## 1.4.4 ENABLING TECHNOLOGIES FOR INDUSTRIAL PROCESSES

**Technology Description**

Improvements in the enabling technologies used broadly throughout industry can provide new operational capabilities, as well as significant energy and carbon savings. Greenhouse gases can be reduced by increasing the efficiency of industrial processes, reducing waste and rework of products, and achieving a longer and more controlled operating lifetime for industrial components. Enabling technologies will increase understanding of the processes and systems required to make products, facilitate improvements, and enable new manufacturing processes. The technologies range from advanced materials, sensors and controls systems, and chemical pathways, to systems and product-oriented design and processing that incorporate environmental and energy benefits in their initial and overall implementation. These types of activities will impact the reduction and more efficient use of energy in current and new industrial processes.

Advanced nickel aluminide materials used in transfer rolls of steel reheat furnaces reduce product defects and reprocessing requirements.

**System Concepts**

- Enabling technologies will complement and be developed cooperatively with other technology pathways, particularly the energy conversion and utilization – as well as the industrial process efficiency – pathways. Enabling technologies will have a positive impact in many industrial areas.
- Increased understanding of processes, development of new materials and control methods, and innovative techniques for fabricating products will impact the entire industrial sector.

**Representative Technologies**

- Advanced materials with attributes such as improved corrosion resistance and the ability to operate at higher temperatures and pressures enable more efficient industrial processes. New thermoelectric materials, for example, can enable recovery of high-temperature waste energy from industrial processes. Material categories under investigation include degradation-resistant materials, thin-film thermoelectric materials, materials for separations, metal alloys, ceramics, composites, polymers, and nano-materials.
- Sensors, controls, and automation enable more robust industrial process operations. Areas of emphasis include inferential controls; real-time, nondestructive sensing and monitoring; wireless technologies; and distributed intelligence to interpret and integrate data from various sensor types to aid in optimizing process control.
- Other enabling technologies with potentially large industrial impacts include combinatorial methods; and predictive modeling and simulations, which complement development of control technology, as well as new product and process design.

**Technology Status/Applications**

- Advances are being made continuously in the development of new materials, including high-temperature materials, new coatings, smart materials, nano-materials, films, and materials with reactive or self-assembly properties. Abundant opportunities remain for developing new materials that can make a significant impact on industrial energy use and emissions (e.g., catalysts, inorganic-organic hybrids, thin film composites, refractories, sensor materials).
- Intelligent controls have been implemented in industry, but are still technically inadequate in a number of areas. Further impacts can be made in global and remote sensing, inferential sensor and control technology; and nondestructive on-line evaluation of process parameters and equipment.
- New computational techniques are emerging every day, but have yet to keep pace with the phenomenal increase in computing power. Experimental methods based on combinatorial techniques – such as those used in drug discovery – could revolutionize the way new materials and products are developed, but are only slowly being adapted to industrial use.

- The use of model-based control systems and neural networks that can "learn" and improve process/energy efficiency will lower emissions of GHG from manufacturing processes.

**Current Research, Development, and Demonstration**

**RD&D Goals**

- Research program goals for this area target new enabling technologies that meet a range of cost goals depending on the technologies and on the applications where they are to be used. Cost targets when considered on a system basis are expected to range between 0.5 to 2 times those of typical technologies.
- By 2010, demonstrate production and application for nano-structured diamond coatings and composites and other ultra-hard materials for use in wear-intensive industrial applications; and develop materials for use in a wide array of severe industrial environments (corrosive, high temperature, and pressure).
- By 2012, demonstrate the generation of efficient power from high-temperature waste heat using systems with thermoelectric materials.
- By 2017, develop and demonstrate integration of sensing technologies with information processing to control plant production.

**RD&D Challenges**

- Develop new, economic material compositions, measurement technologies, and inferential control and predictive maintenance systems.
- Enable increased understanding of chemical, metallurgical, and related processes impacting efficiency process design and control.
- Develop functional and protective materials for sensors, actuators, and other devices deployed in industrial environments.
- Develop materials property/engineering databases for materials used in industrial applications.
- Validate mathematical models to enable improved and integrated process design and operations.
- Scaling up of technologies from the laboratory to commercial application while achieving anticipated economies of scale, maintaining performance goals, and ensuring component integrity.
- Assuring compatibility with real-world manufacturing environment to avoid degrading performance of existing processing and production systems.

**RD&D Activities**

- Development of industrial system components including high-temperature and corrosion-resistant materials used in melting, heat treating, or combustion systems; chemicals and pulp- and paper-processing systems; and boilers and gasifiers.
- Ongoing R&D activities on enabling technologies include the Advanced Industrial Materials and Sensors and Automation projects in DOE. Modeling and simulation activities are supported by DOE throughout all program areas as appropriate. Additional applied research activities are in the Department of Commerce Advanced Technology Program and in the Environmental Protection Agency. Basic research activities are in DOE's Office of Science and the National Science Foundation (NSF).

**Recent Progress**

- Laser Induced Breakdown Spectroscopy (LIBS) technology has been developed to effectively measure the composition of molten metal and glass in real time. The technology, which is now in commercial use, has the potential to reduce energy consumption by 5-10 trillion Btu annually.
- Nickel aluminides have been developed for heat-treating furnace fixtures that last three-five times longer than high-performance steels, and improve production and energy efficiency in carburizing furnaces by as much as 33%.
- Thin intermetallic alloys developed for coating the inside of reactor tubes used in production of ethylene will be used to reduce coke formation, increasing tube life and improving reaction conditions. Potential energy savings could be more than 400 trillion Btu per year.
- A new distillation column flooding predictor has been developed, which will enable petroleum refineries to increase column throughout by 2%-5%, improving safety margins and increasing efficiency and gasoline production for the same amount of energy.

| Commercialization and Deployment Activities |
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| • The industrial segment of the economy is substantial, and enabling technologies are impacting every industrial sector. New materials are being introduced in the manufacturing of steel; new measurement systems and *in situ* temperature measurements in harsh environments have been developed and are being used in industry; and new capabilities in design and modeling methodologies are reducing the energy use and greenhouse gas emissions of production plants.<br>• The introduction of new technologies is often sensitive to initial cost, and cost benefits must be evaluated based on life-cycle benefits.<br>**Market Context**<br>• Applications for enabling technologies are many and encompass the various industrial segments of the economy. Every industry segment will benefit from the activities, and the efforts will be coordinated with other pathways. |