The Path to Agenda 2020: Progress, Products, and Opportunities

Valri Robinson, U.S. Department of Energy, Office of Industrial Technologies
Shawna McQueen and Louise Dove, Energetics, Incorporated

ABSTRACT

To compete in global markets, the forest products industry must reduce its energy use and capital costs, while increasing its productivity and product quality. The industry must also meet strict environmental regulations governing its processing operations. The "Industries of the Future" initiative offers U.S. industries like the forest products industry an opportunity to develop and implement innovative technical solutions to meet these various challenges. This paper discusses the basic features of the initiative and describes progress in developing three promising technologies: 1) On-Site, On-Demand Chlorine Dioxide Generation, 2) the Methane DeNOx Reburner and 3) Multiport Cylinder Dryers. The technologies are expected to have near-term positive impacts on the forest products industry's energy efficiency and environmental performance. Moreover, the new technologies may be transferable to other manufacturing sectors where they will have similar advantages. The Industries of the Future initiative, facilitated by the U.S. Department of Energy's Office of Industrial Technologies, encourages energy efficiency and environmental protection nationwide.

Introduction

The globalization of markets and the emergence of new international competitors create both opportunities and threats for U.S. manufacturing industries. To maintain and enhance their competitiveness in the next century, our industries must stay at the leading edge of quality, innovation, and productivity. Technology will play a key role in ensuring that our industries can meet this challenge while also taking the steps necessary to protect human health and the environment.

The U.S. Department of Energy's Office of Industrial Technologies (OIT) sponsors research and development (R&D) and technical assistance and outreach programs to improve the energy and resource efficiency of U.S. industry. A unique aspect of the OIT program is its approach to working with industry. Recognizing that the largest energy-using industries are its primary customers, the program has been designed to work collaboratively with these and supporting industries to focus R&D and technical assistance where it is most needed.

At the center of OIT's approach is the "Industries of the Future" (IOF) initiative. The initiative concentrates on nine manufacturing industries in the U.S. economy: forest products, agriculture, aluminum, chemicals, glass, metal casting, mining, petroleum refining, and steel. The high cost of energy, capital equipment, and pollution abatement in these industries has made funding long-term R&D difficult even though considerable benefits would be expected from the R&D.

The IOF model calls for activity in three areas, as summarized in Figure 1: 1) creation of an industry **vision**, 2) development of a technology **roadmap**, and 3) implementation of **research partnerships**. At each step, the industry drives the process by identifying specific

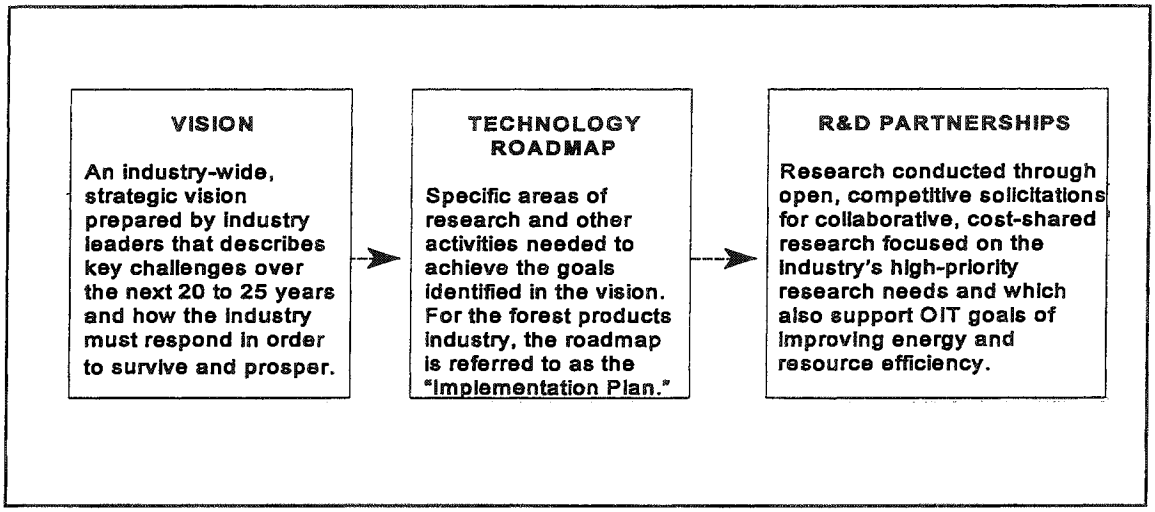

Figure 1. Three basic steps of the Industries of the Future process

issues that affect the industry and R&D activities that will address the issues. OIT facilitates the process by encouraging the industry to undertake long-term technology planning and cost-shared research partnerships focused on increasing energy and materials efficiency and reducing waste and pollution. OIT also provides streamlined access to the resources and capabilities of DOE's national laboratories, and strongly encourages collaborative research projects that combine expertise from the private sector (industry, suppliers, customers, and others); academia; national laboratories; and other key research institutions. This approach reduces the cost and risk of R&D by leveraging funding and pooling scattered pockets of expertise. The new scientific knowledge, technologies, and practical lessons put into use will help position these vital manufacturing industries for continuing prosperity while advancing national energy efficiency and environmental goals.

Agenda 2020 — The Forest Products Industry of the Future

The forest products industry has completed all three steps of the IOF process and has been funding cooperative research projects since fiscal year (FY) 1996. In November 1994, the forest products industry published its strategic vision for the future, entitled *Agenda 2020: A Technology Vision and Research Agenda for America's Forest, Wood and Paper Industry*. The vision names six strategic areas that are suitable for cooperative R&D:

- Sustainable Forestry
- Environmental Performance
- Energy Performance
- Improved Capital Effectiveness
- Recycling
- Sensors and Control

In the next step, specific research pathways were mapped out for each area, which provide the roadmap for moving the industry from where it is today to where it wants to be in the future. The pathways serve as the basis for research solicitations and are reviewed annually. As of March, 1999, a total of 70 cooperative projects have been funded in the forest products industry's "Agenda 2020" process: 67 by OIT and 3 by the U.S. Forest Service.

Progress

Response to Agenda 2020 research solicitations has been outstanding. As Table 1 shows, many more proposals are received each year than OIT can fund. Unfortunately, many excellent proposals on topics of high priority to the industry are rejected because of budgetary constraints or a low-level match between the goals of the project and OIT's programmatic goals. Other agencies and organizations are encouraged to review Agenda 2020 proposals and consider funding them. In a good example of interagency cooperation, the U.S. Department of Agriculture, U.S. Forest Service, funded three projects in the Sustainable Forestry research area in 1998.

Table 1. Agenda 2020 Solicitation Results and OIT Funding Levels

	FY1996	FY1997	FY1998*	FY1999
Pre-proposals Received	179	664	0	396
New OIT Projects Awarded	21	28	0	18
Total Project Funding ($ million)	4.6	7.7	8.7	10.2

* No new OIT starts — funding provided to continue ongoing projects.

Six task groups, established for each of the key research areas identified in the vision, are responsible for implementing the IOF process for the forest products industry. The task groups are coordinated by the American Forest & Paper Association and include members from academia, government, research institutions, and a broad cross-section of industry. It is the task groups that define research needs, issue requests for proposals, and evaluate and recommend proposals for funding. Acting for the U.S. Department of Energy, OIT conducts an independent review of proposals received in response to Agenda 2020 solicitations and makes awards based on a project's importance to the industry, its technical merit, and programmatic criteria such as its potential for energy savings and waste reduction. Forest products companies may not receive direct project funding, but they may participate in projects as part of the research team.

The Agenda 2020 process has been received very positively by the industry. More than 20 pulp, paper, and wood products companies actively participate in the initiative and many more have contributed along the way. A chief benefit of the IOF process is that it brings the industry together to identify common problems and develop solutions that can be

> "*Agenda 2020* has broad acceptance and significant influence both directly in our industry and with the wider community who work with us and support us. It identifies significant [industry] priorities and it raises expectations. It is seen as current, relevant and important...*Agenda 2020* defines and communicates the technology-related gaps that must be addressed to achieve a desired state for this industry in the year 2020."
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> Josephine Cooper, Vice President, Regulatory Affairs, AF&PA

pursued collaboratively through cost-shared research. Another key benefit is the increased participation of universities, national laboratories, and industry suppliers in conducting R&D targeted at the forest products industry's high-priority research needs. The unique partnerships created through the program have enhanced the chances for successful research results that can be applied by industry to achieve economic, environmental, and energy benefits.

Products

This section describes three ongoing projects on the Agenda 2020 roster. These efforts are expected to lead to near-term commercial applications of the technologies and substantial benefits to the industries. Descriptions are provided of

1. High Efficiency, On-Site, On-Demand Chlorine Dioxide Generation;
2. the Methane de-NOx® Reburning Process; and
3. the Design and Demonstration of Multiport Cylinder Dryers.

1. High-Efficiency, On-Site, On-Demand Chlorine Dioxide Generation. The pulp and paper industry must meet strict environmental standards governing its bleaching operations. A bleaching agent with a low-chlorine content such as chlorine dioxide (ClO_2) generates fewer organochlorine compounds and provides an environmentally sound bleaching process for industrial operations. New electrode technologies have the potential to overcome present limitations to the expensive direct electrochemical generation of ClO_2. The objective of this research is to develop an advanced electrochemical system to generate chlorine dioxide cost-effectively, on-site in paper mills. This will ensure the availability of a relatively inexpensive, environmentally acceptable bleaching agent on demand in paper mills.

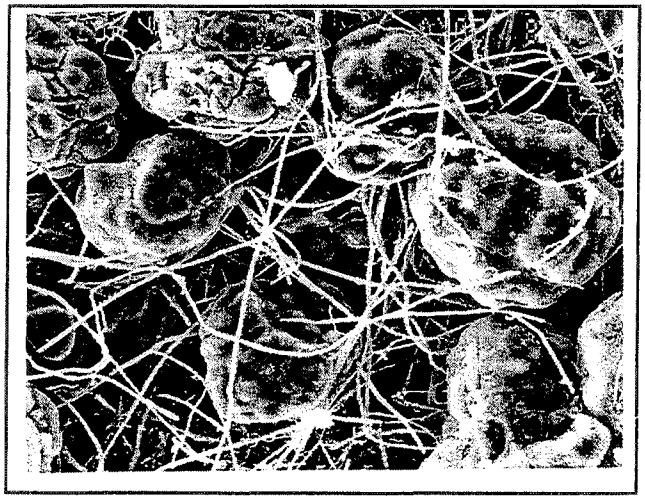

Figure 2. Fibrous catalyst/electrode incorporating carbonaceous particulates

Researchers at Auburn University have invented a new class of composite materials known as Microstructured Microfibrous Materials (MMM) that will be applied to this problem. The three-dimensional materials consist of a matrix of micro-diameter conductive metal fibers that can entrap very small particles of catalysts or electrocatalysts (Figure 2). In other industrial electrodes, there are rate-limiting transport processes within the molecular pores of the catalyst particles or electrode. The MMM allow closer contact between the catalyst and the reactant, resulting in more energy-efficient and rapid processing of chemical streams. These materials allow heterogeneous reactions to occur over the solid particles, and are ideal for fabricating cathodes for the production of ClO_2 (Tatarchuk and Ahn, n.d., 5).

How the cathodes are fabricated. The metal fibers and the secondary particulates (the catalyst/electrocatalyst to be entrapped) are placed into an aqueous slurry of cellulose fibers on a papermaking machine. The resulting mixture is filtered onto a stationary or moving screen to form a sheet of paper, using ordinary papermaking techniques. When dried, it is exposed to a high temperature, which removes the cellulose and fuses the metal fibers at their junctures. The resulting matrix can be coated with active materials, or if secondary catalyst/electrocatalyst particles were present in the cellulose, they become entrapped by the fiber matrix that forms around them. The unique quality of the material now is that it allows the close contact and combination of previously incompatible materials and properties. Papermaking is a proven technology and producing these materials with papermaking technology is relatively inexpensive, although the high-temperature processing steps can be challenging.

How MMM will be applied to the forest products industry. MMM can be used as efficient and cost-effective electrode materials to produce sodium chlorate. This product is then converted into chlorine dioxide for use in paper bleaching. A highly efficient material is presently being tested in the laboratory to be used for electrodes, which shows great potential for lowering the cell voltage of 3.0 V by approximately 400 mV, providing significant electrical energy savings during chlorate production (Tatarchuk and Ahn, n.d., 2).

After various analyses are completed, a commercial partner will be identified to conduct a process simulation. Pilot-scale electrodes will be prepared and additional "aging" studies carried out. Following pilot-scale tests of electrodes, a site will be chosen for an in-plant demonstration.

Benefits of MMM to the forest products industry. The production of chlorate is highly energy intensive, with the cost of electricity accounting for 45 percent of its manufacturing costs. Using a cathode manufactured from the newly developed materials, about 13 percent less energy would be used compared to the conventional production of chlorate (B. Tatarchuk, pers. com. 1999). The direct energy benefit to the industry is estimated to be $60/ton of chlorate (0.4 V of savings for a 3.0 V cell). This has a value of $30 million annually in today's U.S. market of about 500,000 tons of chlorate produced per year. Additional savings will be generated (e.g., in transportation costs) if chlorate is produced on-site at forest product facilities (Tatarchuk and Ahn, n.d., 2).

Availability of the MMM Technology. The MMM technology is available for licensing or for the direct purchase of electrode materials through the Center for Microfibrous Materials Manufacturing at Auburn University, Alabama. The researchers are in the final phase of completing the electrode design and cost studies before selecting an industrial partner to test electrodes in pilot and demonstration programs. For information on the technology, contact Dr. Bruce J. Tatarchuk, Director, CM^3, Department of Chemical Engineering, 230 Ross Hall, Auburn University, AL 36849, (334) 844-2023.

2. The METHANE de-NOx® Reburning Process. Researchers are studying the application of a "reburning" technology called METHANE de-NOx® to reducing the energy use and environmental emissions associated with the forest products industry. The objective is to characterize the performance of the technology in boilers used in the industry's processes, while burning the fuels that are abundantly available in this industry—biomass, wood wastes, and sludges. The data collected will be made available to decision makers in the industry who have the opportunity to apply the technology to their individual operations (J. Rabovitser, pers. com. 1999).

The METHANE de-NOx® technology has been successfully demonstrated in other commercial settings using municipal solid waste (MSW) or coal as fuel. With the technology in place, the combustion systems operated more efficiently, required less maintenance, and emitted significantly fewer nitrogen oxides (NOx), volatile organic compounds (VOCs), and carbon monoxide (CO) compared to conventional reburning and cofiring methods using these fuels (Abbasi et al. 1998, 637; Loviska et al. 1998, 674).

For example, a field evaluation was conducted on a unit with a METHANE de-NOx® retrofit at the Olmsted County Waste-to-Energy facility in Rochester, Minnesota. The unit was designed to burn 90 metric tons/day of MSW, and achieved a 50 to 60 percent reduction in NOx emissions, and a 40 to 50 percent reduction in CO compared to pre-retrofit tests. The unit's thermal efficiency also increased 2.5 percent (Abbasi et al. 1998, 636-37). At the cogenerating Cogentrix plant, a power-producing facility in Richmond, Virginia, a METHANE de-NOx® coal-fired unit has been in continuous operation for over two years. The boiler's thermal performance has increased 2 percent and NOx emissions have fallen 60 percent since the retrofit was commissioned. Since September 1998, all eight boilers at Cogentrix plant have been in continuous operation equipped with METHANE de-NOx® (Institute of Gas Technology 1998, 1).

The Institute of Gas Technology (IGT), original developer of the reburner technology, and its five industrial partners hope to build upon these successes by extending the technology to a new industry and new fuels.

How the METHANE de-NOx® technology works. In contrast to conventional reburning, where the reburning fuel is injected above the combustion zone to create a fuel-rich reburn zone, in the METHANE de-NOx®system, natural gas is injected directly into the combustion zone above the grate, as shown in Figure 3. This provides an oxygen-deficient environment for combustion, and results in a reduction of NOx formed in the coal bed. It also limits its formation through decomposition of NOx precursors to form molecular nitrogen rather than nitrogen oxides (Loviska et al. 1998, 674).

This environment also stabilizes the average combustion temperature, improving the combustion of fuels with a high moisture content (such as biomass and wood). It also provides more uniform temperature profiles, reducing the peak temperature.

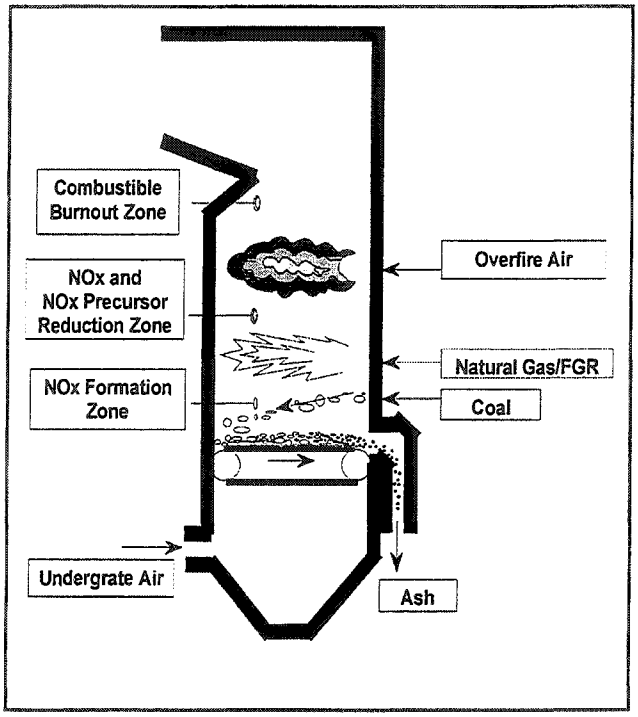

Figure 3. Spreader Stoker Boiler with METHANE de-NOx® Reburn

Higher in the boiler, "overfire air" is injected to complete the combustion process and to hold the emissions and their precursors near the combustion zone long enough to undergo

reburning reactions. This longer residence time in oxygen-deficient conditions not only reduces potential emissions (such as CO), but also extracts more of the potential thermal energy in the fuels by increasing their rate of combustion. The natural gas added to the system should be 8 to 13 percent in heat input, depending on the required reduction in NOx and increase in sludge combustion (Institute of Gas Technology 1998, 1).

Applying METHANE de-NOx® to the forest products industry. Biomass, wood-waste solids, and sludges—fuels already on hand in the forest products industry—have traditionally been difficult to burn in stoker boilers because of their low combustion temperatures and abundant emissions. Baseline tests conducted on a 300-MMBtu/hr waste-wood and sludge-fired facility of Boise Cascade in International Falls, Minnesota, have determined the location of NOx formation, and showed the effects of various boiler environments on NOx emissions and boiler efficiency. Researchers believe there is a high potential for applying the new technology to the boiler to increase sludge feed, reduce the use of auxiliary fuel, enhance efficiency, and maintain environmental standards (Institute of Gas Technology 1998, 1).

A boiler at the Boise Cascade facility will be fitted with the METHANE de-NOx® technology and subjected to short-term and long-term field tests. Three other wood-fired boilers (at other facilities) will also be evaluated directly. Extensive computer modeling and pilot-scale testing will be conducted to support these field tests. Researchers expect to complete the tests on a total of three boilers in 1999. Additionally, they will collect data on the performance of the several hundred boilers that are currently in operation (without retrofits) throughout the forest products industry (J. Rabovitser, pers. com. 1999). The results of these tests and studies will be transferred to a database and used to develop engineering designs of the technology appropriate to a range of wood- and sludge-fired boilers. A commercialization and business plan will be prepared to transfer the successful technology to the forest products industry (Institute of Gas Technology 1998).

Benefits of METHANE-de-NOx® to the forest products industry. Although studies of this system will continue until early 2001, its demonstration in a municipal solid waste combustor and an independent power production facility indicate that it is relatively easy to install the METHANE-de-NOx® technology as a retrofit. The process does not require any modifications of the boiler itself and the capital cost for the retrofit is also relatively low. By 2001, information will be available to individual facility operators on how the technology applies to their specific situations, including the details needed for engineering designs for various boilers (J. Rabovitser, pers. com. 1999).

In adopting this technology, the forest products industry is expected to increase its use of biomass, wood wastes, and sludges, which are available as by-products of its production processes. Based on baseline test results from a 300 MMBtu/hr waste-wood and sludge-fired boiler, researchers have projected that the METHANE-de-NOx® system will significantly reduce the industry's energy use, air emissions, and waste-handling and landfilling costs. When deployed to the forest products industry, the technology's average benefits are expected to be in these ranges (Institute of Gas Technology 1998, 4):

- An increase in the volume of sludge fired in a boiler of from 1.2 tons/hr to 4.5 tons/hr, equal to 26,400 tons/yr
- Savings of $396,000 in annual fees for disposing of sludge from each boiler

- A reduction of 25 percent in the amount of auxiliary fuel (natural gas) injected, equal to 108,000 MMBtu/yr, worth $270,000 per boiler per year
- An increase of 2 percent in thermal efficiency of the boiler, equal to 0.05 x 10^{12} Btus annually; when combined with natural gas savings, savings equal to 0.16 x 10^{12} Btu/boiler/yr
- A reduction in emissions of NOx of >50 percent, or 220 tons/boiler/year
- A reduction in the emissions of VOCs and CO of 50 percent compared to baseline conditions
- Savings for the industry of about $670,000 per boiler in annual operating costs

Availability of the METHANE-de-NOx® technology. The Detroit Stoker Company of Monroe, Michigan, is licensee for the technology that is available now, and can retrofit a facility now. However, after the researchers complete their studies and develop a database, engineering designs for a variety of boilers, and a report, more information will be available to individual facility operators. The database should be completed in 1999, and the final designs by early in 2001. The entire research project will end in the spring of 2001.

3. **Design and Demonstration of Multiport Cylinder Dryers.** The pulp and paper industry is the most capital-intensive manufacturing industry in the United States (DOE 1998). The large dryers that remove residual water from the paper are the costliest components associated with papermaking. These dryers also consume more energy than other components of the paper machine, and offer significant opportunities for applying efficiency measures.

If the industry is to become more productive, methods are needed to increase the evaporation rate of the dryers and lower their energy use. A higher evaporation rate will reduce the number of dryers needed during paper processing. A lower use of steam will ensure the most economical drying operation.

The objective of this project is to apply a compact heat exchanger to a multiport dryer design and to cost-effectively retrofit the technology in existing steam-heated cylinder dryers to obtain the maximum drying rate. Projections are that this radical design can increase the drying rate by up to 30 percent over that of conventional cylinder dryers (S. Choi, pers. com. 1999).

Comparing the conventional technology to the Multiport Cylinder Dryer. In most papermaking machines, the wet web (containing 55 to 60 percent moisture) is passed over a series of rotating steam-heated drying cylinders. The water is evaporated from the paper and carried away by ventilation systems. The heat energy for drying the paper comes from steam as it condenses inside the dryer cylinders. On high-speed machines, a layer of condensate forms inside the cylinder, which interferes with heat transfer during the drying operation (Smook 1997, 267).

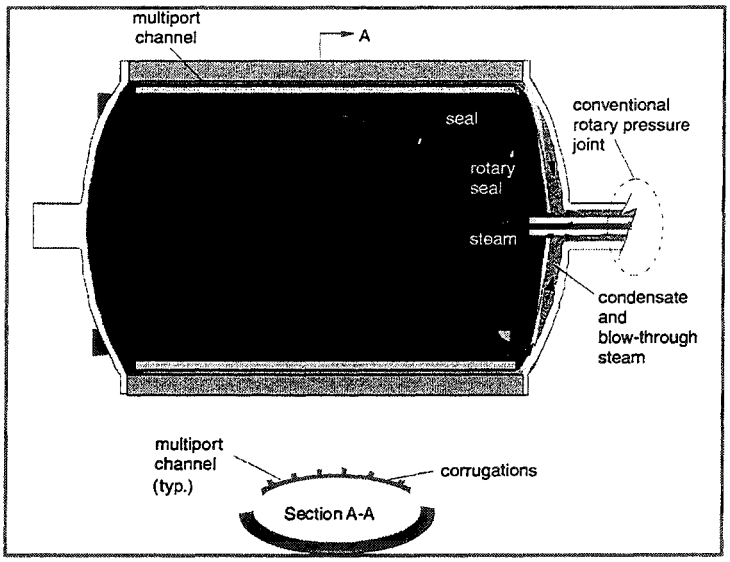

Figure 4. Multiport Cylinder Dryer Concept

In a multiport dryer, the steam flows through "ports," or longitudinally oriented passages, close to the dryer surface (Figure 4). This design minimizes the "rim of condensate" and offers a larger surface area for drying, thereby increasing the drying rates. It also uses forced heat convection, which is more effective as a heat-transfer mechanism than heat conduction.

Applying the Multiport Cylinder to the forest products industry. Researchers at Argonne National Laboratory and their collaborators at the University of Illinois at Chicago, the Johnson Corporation, and Eastern Pulp and Paper will develop and demonstrate a multiport technology that can be cost-effectively retrofitted to existing cylinder dryers to increase their drying rates.

Scoping calculations have been conducted to better understand the steam-condensation process and to gather data for the experimental design of the dryer. Extensive testing and data analysis are underway on the multiport-dryer test apparatus, and modifications are being made to the design as appropriate. When the laboratory-scale tests and assessments are finished, a prototype dryer will be built, installed, and tested in an advanced pilot paper machine. After collecting data on the pilot machine, the technology will be transferred to dryer equipment suppliers to make it ready for the commercial market. The project is expected to be completed by November 1999 (Choi et al. n.d.).

Projecting potential benefits to the pulp and paper industry. The industry is faced with increasing competition in the marketplace from overseas producers. A significant advance in drying technology would enhance the ability of U.S. manufacturers to compete successfully with their products. The technology will offer the following benefits to the industry:

- Increases the production of paper in existing machines by up to 30 percent, according to a computer model of the retrofit (DOE 1998)
- Reduces production costs because of increased annual production (Choi et al. n.d., 1)
- Reduces the diameter and wall thickness of new dryer equipment by 50 percent or more compared to present dryers (DOE 1998)
- Saves energy through removal of condensate load (Choi et al. n.d., 1)
- Improves the paper industry's global competitiveness by reducing the costs for manufacturing its products (Choi et al. n.d., 2)

Applying the Multiport Cylinder to other industries. The automobile industry has already adopted the general approach of a high-performance, compact, multiport condenser to improve the performance of the condensers in its commercial air-conditioning systems. The multiport heat-exchanger technology has been demonstrated successfully in other fields. When this innovative concept is fully adapted for drying paper in the pulp and paper industry, it may find application in additional industries where drying is a crucial processing step.

Further technology transfer will occur through a final report on this project, and the distribution of other reports and papers documenting the research and development of the technology.

Opportunities

There are a number of opportunities for organizations in the public and private sector to participate actively in OIT's Agenda 2020 initiative.

Upcoming solicitations. The selection process is currently underway for FY2000 projects. FY2001 solicitations will begin in August 1999 with the release of *Request for Proposals* from the Forest Products IOF task groups. Information on the upcoming solicitations may be found on the OIT Forest Products home page on the Internet (www.oit.doe.gov/forest), or at a separate web site developed by industry for Agenda 2020 (www.agenda2020.org).

In July 1999, DOE's Office of Energy Efficiency and Renewable Energy (EERE) will launch an exciting new initiative to advance the development and implementation of gasification technologies. The impetus for this initiative has largely been provided by the forest products industry, which is poised to demonstrate emerging biomass and black liquor gasification technologies (black liquor is the residual chemicals from the kraft pulping process.) Biomass-based gasification could become a very significant technology for the forest products industry as the conventional recovery boilers operating in pulp and paper companies reach the end of their service life within the next fifteen years, and will need to be replaced. According to the American Forest & Paper Association (1998), preliminary findings indicate that benefits of gasification would include

- an increase of up to 10 percent in thermal efficiency,
- three times more kWh of electrical power generation per ton of biomass,
- offsets of 30 to 60 million metric tons of carbon per year in fossil-fuel carbon emissions,
- elimination of the danger of smelt-water explosions,
- 5 percent improvement in the efficiency of kraft chemical recovery, and
- a reduction in capital and operating costs.

Although biomass and black liquor gasification technologies have been under development for a number of years, commercial demonstration and testing of the alternative technologies are required to move them into industrial use. The forest products industry is highly motivated to participate in commercial demonstrations of gasification technologies. However, the high financial risk of being a "first adopter" (estimated at $30 million to $60 million in *additional* costs) represents a significant barrier to carrying this out. The forest products industry is hopeful that the gasification initiative will cost-share the demonstrations with industry and accelerate the commercialization process. By demonstrating these technologies in the forest products sector where there is a high likelihood of success, it will also facilitate transfer of the technology to other energy-intensive industries, such as chemicals, refining, food processing, and utilities.

Other OIT programs. The Forest Products IOF initiative coordinates with other programs in DOE's Office of Industrial Technologies to offer a full range of products and services to the forest products industry. Crosscutting research applicable to multiple process industries is conducted in the Advanced Industrial Materials, Combustion, Continuous Fiber Ceramic Composite Materials, Sensors and Controls, and Industrial Power Generation programs. Technical assistance programs encourage adoption of commercially proven energy efficient technologies and "best practices." These programs include Motor Challenge, Combined Heat and Power Challenge, Steam Challenge, Compressed Air Challenge, and Industrial Assessment Centers. And finally, two financial assistance programs provide grants to help develop and demonstrate innovative technologies: (1) NICE^3 (National Industrial Competitiveness through Energy, Environment, Economics) offers cost-shared grants of up to $400,000 to state-industry partnerships that can demonstrate technologies promoting energy efficiency, clean production, and economic competitiveness; and (2) the Inventions and Innovation program provides grants

of up to $100,000 to individual inventors and small companies with promising ideas for improving energy efficiency and environmental performance. All of these programs work closely with OIT's Forest Products IOF team to identify and evaluate opportunities to assist the industry. Information on these programs and their associated solicitations may be found on the OIT home page (www.oit.doe.gov).

Conclusion

Increasing international competition in both export and import markets makes it absolutely essential for the U.S. forest products industry to adopt new technologies that can reduce operating costs and improve productivity. In most cases, energy is the third-highest operating cost after materials and labor, and is recognized by the industry as a primary target for cost reduction. Through the Forest Products IOF initiative, the industry is working with researchers from academic institutions, national laboratories, and other world-class research organizations to create innovative technical solutions to their common problems. The industry gains technology improvements and knowledge that will help improve its productivity, reduce costs for energy usage and environmental compliance, and improve safety for workers and the community. The Nation as a whole also receives benefits, including major reductions in fossil-fuel-related greenhouse gas emissions; improved industrial energy efficiency; significant reductions in volatile organic compounds, chlorine-containing compounds, and other pollutants; less dependence on fossil fuels; and improved competitiveness of an industry that employs more than 1.3 million workers, generates more than $267 billion in shipments each year, and has a profound effect on the U.S. economy.

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