DOE/OIT PLANT-WIDE ENERGY ASSESSMENT EXPERIENCE SUMMARY*

Mitch Olszewski, Robert Leach, and Karen McElhaney
P.O. Box 2008
Oak Ridge National Laboratory
Oak Ridge, TN 37831

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MITCH OLSZEWSKI
ORNL BESTPRACTICES PROGRAM MANAGER

ROBERT LEACH
PROGRAM MANAGER

KAREN McELHANEY
RESEARCH ENGINEER

OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TN 37831

ABSTRACT

The Department of Energy (DOE) Office of Industrial Technologies (OIT) is sponsoring cost-shared, plant-wide energy assessments of industrial facilities through its BestPractices Program. The purpose of these assessments is to examine plant utility and process operations and to identify opportunities for improving their energy efficiency. During the past 18 months, DOE has awarded grants to a total of 13 plants in the steel, metal casting, aluminum, forest products, chemical, and petroleum industries. All of these industries are part of the DOE Industries of the Future (IOF) Program.

The average annual savings identified in these studies has been more than $1,000,000 per facility, with payback periods usually less than 18 months (some have been as short as 3 months). In some cases, the nonenergy benefits identified (e.g., reduced scrap, increased productivity, and maintenance reductions) have been greater than the energy savings. This paper summarizes the findings from the completed assessments and identifies common areas where energy savings opportunities have been found.

BACKGROUND

In partnership with industry, the U.S. Department of Energy (DOE) Office of Industrial Technologies (OIT) is helping to develop, demonstrate, and deploy technologies that could save energy and reduce greenhouse gas emissions. Through OIT's customer-driven Industries of the Future (IOF) strategy, industry has greater influence in setting public research and development (R&D) priorities and improved access to a wide array of technical expertise and facilities. The result is savings in energy and materials, cost-effective environmental compliance, increased productivity, reduced waste, and enhanced product quality. Through its customer-driven IOF strategy, OIT encourages energy-intensive industries to work together to

- create broad, industry-wide goals for the future;
- identify specific needs and priorities and ways to achieve them; and
- form cooperative alliances to help attain identified goals through technology partnerships.

The IOF strategy creates partnerships among industry, government, and supporting laboratories and institutions to accelerate technology R&D and deployment. Key elements of the IOF strategy include an industry-driven document, which outlines the industry's vision for the future, and a roadmap to outline the technologies needed to reach its goals. Through this process, government cost-shared R&D is focused to benefit U.S. industry.

The OIT BestPractices Program provides integrated delivery of energy-saving products, services, and technologies to the nine IOF sectors: agriculture, aluminum, chemicals, forest products, glass, metal casting, mining, petroleum, and steel industries. These nine industries use more than 75% of the energy consumed in all U.S. manufacturing (1). In coordination with the industry-specific and industry-wide programs of the OIT, BestPractices provides technical assistance to help these industries increase energy efficiency, reduce waste, and boost productivity.

The BestPractices technical assistance targets immediate cost-saving opportunities and productivity improvements for IOF customers. Technical assistance includes a continuum of services—from energy assessments and evaluations, through information on industrial equipment and systems, to tools and resources for measuring the effectiveness of new technologies.

The DOE objective in sponsoring plant-wide energy assessments is to increase the participants in the IOF group and to develop broad coverage across the United States. The goal is to establish a solid database that can be used to assess and disseminate

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technology for reducing energy usage in the nine IOF industries. The OIT selection strategy has been to choose a diverse range of manufacturing plants in an effort to gain a balance across the IOF sectors and to seek diverse technical approaches. To understand how differences in energy prices, climatic conditions, and other factors affect the optimization strategy, a wide range of geographic locations and plant sizes (i.e., number of employees or size of energy bill) has been considered.

Industrial facilities chosen for the plant-wide energy assessments had expressed a specific interest in the identification of projects that demonstrate the benefits of a systems approach across an entire manufacturing plant. This approach generally consists of two project phases. The first is to identify applications that offer the greatest energy conservation potential by compiling a profile of energy consumption. The second is to assess specific actions in each of the high-priority areas. Assessments are targeted to cover a variety of energy-efficient technologies and "best practices" associated with plant support systems such as steam systems (e.g., generation, delivery, use, and recovery), combined heat and power systems, process heating systems, electric motor systems (e.g., pump and fan systems), and compressed air systems. The participants are also encouraged to assess new and emerging state-of-the-art technologies that can affect overall process efficiency and productivity improvement. Unique approaches that examine plant operations but have an indirect effect on energy use (e.g., reducing peaks and valleys in production schedules can yield energy reduction benefits) have also been encouraged. The assessment of energy-efficiency gains identified as indirect benefits by using these methods is also supported.

Analysis is focused on identifying projected cost savings and capital costs, including energy savings and nonenergy factors such as maintenance benefits or costs, operating benefits and costs, reduced downtime benefits and costs, and environmental impacts. Lessons learned from the plant assessments and associated projects are used to implement similar projects at other plants within the same company or at other industries with related applications.

To date, three rounds of plant-wide energy-efficiency solicitations have been issued. In Round I, FY 2000, six plants were selected to participate in the assessments. Plants selected in this round were Alcoa Lafayette, Indiana, Operations; the Amcast Wapakoneta, Ohio, plant; the Boise Cascade International Falls, Minnesota, mill; the Caraustar Rittman, Ohio, mill; the Crucible Utica, New York, plant; and the Inland Paperboard and Packaging Rome, Georgia, mill. Assessments have been completed and documented at all but Crucible, which is currently in the final stages of its project.

For Round II, FY 2000-2001, seven awards were allocated. Winners for this round were the Akzo Nobel Morris, Illinois, plant; the Anchor Glass Container Warner Robbins, Georgia, facility; the Appleton West Carrollton, Ohio, plant; the Metlab Philadelphia, Pennsylvania, plant; the Paramount Petroleum facility in Paramount, California; the Utica Corporation Whitesboro, New York, plant; and the Weyerhaeuser Longview, Washington, plant. These assessments are scheduled for completion during calendar year 2001.

The solicitation for Round III closed on November 22, 2000. Selection of Round III winners is in progress.

RESULTS OF ASSESSMENTS

Alcoa Lafayette Operations

Alcoa Inc., is the world's leading producer of primary aluminum, fabricated aluminum, and alumina. Alcoa is active in all major segments of the aluminum industry, including mining, refining, smelting, fabricating, and recycling. Alcoa provides packaging, automotive, aerospace, construction, and other markets with a variety of fabricated and finished products. The company is composed of 24 business units, with 103,500 employees at 215 operating locations in 31 countries. Revenues in 1998 were $15.3 billion.

Lafayette Operations is an aluminum extrusion plant that is part of the Alcoa Engineered Products Business Group. Processes at this facility include ingot casting, extrusion, and cold-drawn tubing production. Finishing operations associated with extrusion include stretching, sawing, heat treating, and annealing. Tube production involves the cold-drawing of extruded tube. The drawing process produces flexible, thin-walled tubing that can be used in a variety of applications in many industries.

The objectives of Alcoa's energy study were to analyze departmental energy use, identify areas for more detailed analysis, evaluate several of the energy-saving opportunities identified, and support the development of a comprehensive energy strategy for the facility. Alcoa's assessment team consisted of Pace Global Energy Services, LLC; SSEEI, Inc.; and

Veritech. Areas selected by the team for detailed analysis follow:

- high-pressure extrusion press pumps,
- extrusion Unit 2 billet heaters,
- ingot plant cooling water recirculation system,
- compressed air system,
- plant lighting,
- plant steam boilers,
- melting furnaces, and
- energy monitoring.

The team found that implementation of energy conservation projects could result in an annual savings of $1,974,300 in the eight areas of interest with an estimated initial capital requirement of $2,308,500. Of the total savings, $1,309,300 is direct energy savings, and $665,000 is nonfuel operating and maintenance costs. The resulting payback period would be approximately 1.2 years. Specific areas that represent the greatest savings opportunities include

- extrusion press pump improvements,
- just-in-time billet heating,
- compressed air system improvements,
- ingot cooling water recirculation systems,
- direct-fired heating system,
- melting furnace heat recovery,
- furnace maintenance, and
- monitoring and targeting.

Amcast Wapakoneta

Amcast is a supplier of aluminum permanent cast suspension components for the automotive industry and also serves construction and other industrial sectors. The manufacturing facility located in Wapakoneta, Ohio, employs approximately 300 people. The facility processes a total of 20 to 25 million pounds of aluminum annually. The key objective of their study was to identify and recommend ways to cost-effectively reduce waste, energy, and operating costs.

At the Wapakoneta facility, raw material comes into the plant in the form of aluminum ingots. Natural-gas-fired reverb furnaces melt the aluminum ingots. The molten aluminum is then transferred to the hold furnaces adjacent to each low-pressure permanent mold machine via electrically heated ladles. After casting, flash and scrap parts are sent back to a Jet-melt furnace. Cast products are trimmed, inspected, heat-treated, and artificially aged in aging ovens. Primary waste streams include aluminum dross, recyclable aluminum flash, deburring material, metal shavings, and cooling wastes.

The plant-wide energy assessment was conducted to identify significant energy, waste, pollutants, and productivity loss generators in the aluminum metal casting industry. The project was a joint effort with Amcast, the University of Dayton, Ohio's Energy Efficiency Office, Miami Valley Diagnostics, Capital Surini Group International, Inc. (CSGI), and the Edison Materials Technology Center (EMTEC).

The assessment team identified 13 specific projects to reduce energy and waste production. These included implementation of new fill tube material and clamping systems, installation of high-efficiency electric die heating equipment, renovation of the plant compressed air system, and improvement of metal melting processes and configuration.

Improvements in the process section of the facility are expected to result in the most significant savings. These measures coupled with energy and scrap reduction efforts are estimated to translate to an annual savings of more than $3,600,000. Total project costs are estimated to be $1,000,000, resulting in a payback period of only 3 months. Additionally, annual CO_2 reduction is estimated to be 11,000,000 lb. Based on the analysis and projections developed by the team, the annual savings derived from the assessment provides immediate returns with minimum cost and maximum payback.

Boise Cascade International Falls Mill

The Boise Cascade Mill in International Falls, Minnesota, is an integrated pulp and paper mill that produces 1500 tons/d of finished paper from four paper machines using site-cooked pulp and purchased slurry and stock.

The International Falls mill has traditionally implemented heat recovery projects and has been energy conscious. The mill has achieved favorable ratings in energy use benchmark comparisons and has competitive energy contracts in place for other energy resources. In an effort to identify additional energy savings opportunities, the mill chose to use water pinch technology as an analysis tool. The analysis identified several heat recovery projects and process modifications to help achieve the mill's energy reduction goals.

The Boise Cascade International Falls Mill staff conducted a thermal pinch study in 1997. Recommendations from the study included several projects that would increase the thermal energy efficiency of the mill. The mill staff wanted to adopt a similar site-wide approach to address water use issues and their association with fiber and energy costs and

product quality issues. The assessment team consisted of Boise Cascade International Falls Mill, American Process, Inc., and the Electric Power Research Institute (EPRI).

Water pinch analysis is used to identify synergies between water and energy reduction associated with the pulping and paper-making processes. This technique, combined with an examination of energy use at the effluent treatment plant, provides insight into site-wide water and energy consumption. The approach is derived from the combination of water conservation efforts with input from specific field experiments that account for quality constraints and economics. A site-wide approach was adopted to prevent changes to one process from adversely affecting other processes. The approach can be applied to all paper machine sites.

A total of 17 potential projects were identified to assist in effluent reduction. Of these, four projects and two process modifications were selected as the most practicable to attain the reduction goal. These projects are estimated to cost $2,100,000 (±25%). Savings of $707,000/year and a payback period of 3 years were estimated.

These projects and modifications in total would remove 45.6 MM Btu/h from the effluent, exceeding the reduction target of 35 MM Btu/h estimated from the study. In addition, the projects would reduce steam use by 28,100 lb/h and effluent flow by 2.2 Mgd (an 8% reduction in total flow). Because the reduction target could be achieved with the selected projects, the remaining 13 water conservation and effluent heat reduction projects were postponed but may be implemented in the future to further increase mill efficiency.

Additional benefits from implementation of selected projects and modifications include reduced consumption of filtered water, raw water, and demineralized water, as well as effluent flow reduction and steam savings.

Caraustar Rittman Mill

Caraustar is a major manufacturer of recycled paperboard and converted paperboard products. Caraustar manufactures its products primarily from recovered fiber derived from recycled paperstock. At its 16 paperboard mills, Caraustar produces various grades of uncoated and clay-coated recycled paperboard both for internal consumption and for sale to customers in four principal markets:

1. tubes, cores, and composite containers;
2. folding cartons;
3. gypsum wallboard facing paper; and
4. miscellaneous specialty and converted products.

In addition to its mills, Caraustar's facilities include tube and core converting plants, composite container plants, folding carton plants, and specialty converting plants. The company's principal manufacturing activity is the production of uncoated and clay-coated recycled paperboard. In this manufacturing process, paperstock is reduced to pulp, cleaned and refined, then processed into various grades of paperboard for internal consumption or sale in the four principal markets. Approximately 32% of the recycled paperboard sold by Caraustar's mills is consumed internally by its converting facilities; the other 68% is sold to other paper markets. Caraustar conducted its plant-wide energy assessment in association with Sterling Energy Services, LLC, at the Rittman, Ohio, recycled paperboard plant. The Rittman plant produces gypsum wallboard and clay-coated boxboard.

Caraustar's assessment team conducted comprehensive plant energy-efficiency reviews using a systems approach combined with industry standard practices. Opportunities for energy savings were identified and documented, then evaluated and prioritized based on potential for energy savings. Maintenance practices and operating procedures were also reviewed for their impact on energy efficiency. The company had already implemented detailed reporting practices for quantifying process input and output before initiation of the energy assessment. The primary focus of the energy assessment, therefore, was to evaluate the efficiency of the plant processes.

The plant-wide study concentrated on identification of energy-efficiency improvements for the Rittman mill, with an extended focus on the development of efficiency concepts that could be transferred to other Caraustar facilities. Many of the efficiency measures identified and evaluated in this assessment will benefit other Caraustar and related industries:

- motor procurement and efficiency improvements,
- backpressure steam turbine generators,
- boiler feed pump variable-speed drives,
- stack heat recovery to vapor-absorption systems,
- pulper fill-water heat exchangers, and
- steam pipe insulation.

Application of these energy-efficiency measures is being reviewed for other mills. In addition to the efficiency measures identified, other measures were found that did not offer immediate benefits to Rittman, but they could provide some benefits to other Caraustar facilities. Areas identified that might result in potential benefits for other mills included

- boiler forced-draft fan variable-speed drives, and
- paper machine dryer-section drive retrofits.

Before initiating the energy assessment, Caraustar had already undertaken a project to inventory electric motors at selected mills to identify savings opportunities that could be realized from implementation of a formal motor management program. The plant-wide energy assessment permitted the project team to accelerate the motor management effort. As a result, Caraustar has implemented a corporate procurement program for electric motors and power transmission and related industrial equipment that has reduced the cost of purchasing these items and boosted the opportunities to improve the overall efficiency of each plant's motor inventory.

Inland Paperboard and Packaging Rome Mill

Inland Box Corporation was formed in 1925 as a producer of corrugated boxes. Two decades later, a joint venture formed with Mead Corporation resulted in the construction of the Rome, Georgia, linerboard plant. The Rome plant now has two paper machines that produce an average of 2400 tons/d of linerboard, used as the facing sheet in the construction of corrugated cardboard boxes. To support these paper machines, the plant has hardwood and softwood pulp production lines (digesters and washers), power and recovery boilers, black liquor recovery processes, chip and log chipping facilities, utility support systems, and wastewater treatment facilities.

Inland recognizes that it is being affected by increasing global competitiveness at the same time that its process equipment is aging and losing efficiency. The company became interested in a plant-wide energy-efficiency assessment at the Rome paper mill to improve its energy efficiency, increase quality and productivity, and decrease energy costs to increase its global competitiveness. It is the mill's objective to eliminate fluctuating energy costs and to decrease the energy cost burden (measured in fuel expenses, including purchased electricity) by 5% per year for four consecutive years, beginning in 2001. This is in addition to other supply-side efforts to improve the site power production facility by adding gas turbine generation and waste heat recovery to replace aging and inefficient boilers. Additional perceived benefits of the plant-wide study included reduction in solid waste and effluent stream flow and environmental air emissions.

The assessment was conducted during the spring and summer of 2000. The study objectives were to identify energy savings projects in the No. 2 paper machine area and in the fiber plant. The study addressed mill-wide steam and power use, focusing primarily on the demand-side (energy consumption) systems; but implications for improvements in the supply-side (energy production) systems were also considered. The primary goal was to produce a plan to reduce the quantity of steam generated as a by-product. A secondary goal was to reduce the mill's freshwater use. One of the focal points of the study was the mechanical drive steam turbines on the No. 2 paper machine. The study analyzed the technical, operational, reliability, and financial consequences of replacing the two existing steam turbines with variable-frequency motor drives. Along with the turbine study, the steam and condensate system of the No. 2 paper machine was analyzed, and the use of heated water around the machine was investigated. The effects of water and steam reductions at the machine and its support systems (i.e., the steam distribution and pressure-reducing systems to the steam turbine generators in the power house and the steam boiler supplying them) were also analyzed.

The project was a joint effort involving Inland Paperboard and Packaging, Dean Oliver, ITT Gould, Rockwell International, and EPRI.

Thirty-one energy savings opportunities were identified as a result of the energy assessment. These were divided into two categories: projects for near-term implementation and those for future evaluation. Twenty-three favorable opportunities were grouped into seven projects for implementation in 2001–2004. Projects are scheduled such that the average yearly implementation cost is approximately $4,500,000, for a total expenditure of about $18,000,000 for the 4-year implementation period. Projected cost savings are approximately $9,500,000 annually. Projected savings will be realized from a combination of reduced fiber loss; reduced water, steam, and electricity use; and from increased power generation capacity. Other expected benefits include maintenance and reliability savings and reduced equipment downtime, as well as reductions in air emissions, effluent, water intake, and landfill use.

A rebalancing of the steam distribution system was an expected outcome of the energy

assessment. Preassessment analysis showed that more electrical power could be generated from the mill's steam turbine generators than the less-efficient mechanical steam turbines being taken out of service at the paper machine. This change would reduce the amount of power purchased from the local utility. In addition, replacement of the paper machine's mechanical steam turbines with variable-frequency drives would provide an opportunity for significant power factor correction. Steam generation reduction, fuel use reduction, and shutdowns of the least efficient boilers would also have positive consequences on air emissions to the environment. Efficiency improvement projects identified for the Rome plant should be applicable to other U.S. paper plants.

CONCLUSIONS

The average annual savings identified in the energy-efficiency improvement studies has been more than $1,000,000 per facility, with payback periods usually less than 18 months (some have been as short as 3 months). In some cases, the nonenergy benefits identified (e.g., reduced scrap, increased productivity, and maintenance reductions) have been greater than the energy savings. Specific results from the Round I assessments follow:

The energy-efficiency assessment performed at Alcoa's Lafayette Operations aluminum extrusion plant identified potential annual savings of $1,974,300 in eight high-energy-use areas with an estimated initial capital requirement of $2,308,500.

Amcast's assessment highlights the synergy of process performance and its impact on overall energy and cost savings. The findings also demonstrate the need to identify and consider all contributors in defining the performance of a manufacturing facility and associated costs. Amcast has keyed in on these opportunities and has implemented programs to capture projected savings. Although several incremental improvements were identified, the primary focus will be to address the high-rate-of-return items immediately and capitalize on the $3,600,000 annual savings opportunity.

An integrated, effluent heat reduction and water conservation study was performed at the Boise Cascade plant in International Falls, Minnesota. Implementation of four projects and two process modifications is projected to remove 45.6 MM Btu/h from the effluent.

Energy is one of Caraustar's largest operating expenses. Electricity, natural gas, coal, and oil are used in the production of recycled paperboard. Caraustar tracks cost per ton of paper produced in its Mill Group; as a result of this project, it has begun to document energy costs for the Industrial & Consumer Products and Packaging divisions. The plant-wide energy assessment project has been an important component in extending Caraustar's focus on energy efficiency and cost reduction measures in all divisions. Implementation of only three of the projects identified in Caraustar's energy assessment is projected to result in annual savings of $1,200,000 from an initial investment of $3,000,000.

Thirty-one energy savings opportunities were identified in a plant-wide energy assessment at Inland Paperboard and Packaging's Rome, Georgia, paper mill. Potential projects resulting from these opportunities were divided into two categories: those for near-term implementation and those for future evaluation. Seven projects identified for implementation in 2001–2004 are scheduled such that the average yearly implementation cost is approximately $4,500,000, for a total capitalized expenditure of approximately $18,000,000 in the near term. Projected annual cost savings resulting from implementation of these seven projects are $9,500,000.

Seven awards were allocated in Round II. Winners for this round were Akzo Nobel, Anchor Glass Container, Appleton, Metlab, Paramount Petroleum, Utica Corporation, and Weyerhaeuser. These assessments are scheduled for completion during calendar year 2001. Selection of Round III winners is in progress.

Additional information on IOF activities and BestPractices products and services can be found at http://www.oit.doe.gov.

REFERENCE

1. *Turning Industry Visions Into Reality*, U.S. Department of Energy, Office of Industrial Technologies, February 1999.