Energy Conservation Opportunities in the Pulp and Paper Industry: An Illinois Case Study

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ABSTRACT

Demand-side power management in the forest products industry is a promising approach for significantly reducing energy consumption. The forest products industry consumed more than 3.1 quads of energy in 1994. This represents about 14% of domestic manufacturing energy use, making the forest products industry as a whole the third largest industrial consumer of energy, behind only petroleum and chemicals. Within the forest products industry, the pulp and paper industry (SIC 26) uses the vast majority of the energy, 2.66 quads, while the lumber and wood products industry uses only 0.491 quads.

Cost savings achieved from energy assessments of the pulp and paper industry are significant. Records of 376 plant energy audits conducted from 1992-2002 reveal that the average cost savings from implemented measures was $34,122 per facility, averaging 5.2% of each plant's total energy budget.

Recent assessments of pulp and paper plants indicate that even greater energy savings are possible. Combining a strategic energy management approach with the U.S. Department of Energy's Industries of the Future program, savings of up to 15% of a plant's total energy budget are feasible. If realized, these reductions will result in an average annual savings of 1,175,000 kWh and 9,500 MMBtu per plant.

This paper presents an effective energy conservation and management approach using tools provided by the Department of Energy's Best Practices Program, specifically the Compressed Air Challenge, Motor Decisions Matter and Steam System Opportunity Assessment for the pulp and paper industry. Using this approach on a national scale, a significant reduction in energy usage and corresponding cost savings can be achieved, significantly impacting the national energy grid.

Introduction

The University of Illinois of Chicago's Energy Resources Center (ERC) and Industrial Assessment Center, under contract with the Illinois Department of Commerce and Economic Opportunity and the U.S. Department of Energy (USDOE), conducted energy assessments of ten paper and paperboard manufacturers in the Chicago metropolitan area. These assessments were conducted from November 2001 to December 2002, and concentrated on the prime energy users in each plant. Significant opportunities for energy conservation, and therefore cost savings, were determined in each of these plants. Major energy using systems were identified, including compressed air, process steam, process motors, lighting, and heating. These measures not only have the potential to conserve energy, but also to reduce carbon dioxide emissions. Energy conservation opportunities (ECOs) identified for the assessment of the ten facilities can be applied to pulp and paper manufacturing facilities throughout the United States. The US DOE Office of Industrial Technologies provides tools and tips to assist industrial facilities in improving energy usage, which can be applied to a facility's energy management program to reduce energy consumption.

Industry Overview

National

The U.S. forest products industry is an integral part of the nation's economy. This industry employs 1.5 million people and ranks among the top ten manufacturing employers in 42 states, with an estimated payroll of $51 billion. Sales of U.S. forest and paper products exceed $250 billion annually in domestic and export markets (Moore, 2001). The United States produced 88 million tons of paper and paperboard in 1999, over 700 pounds for every man, woman and child, and is the world's largest producer of forest products (OIT, 2002).

Forest and paper industry products represent more than eight percent of the country's manufacturing output and rank sixth among domestic manufacturing sectors, using an extraordinary amount of energy in the process. Since 1972, the industry has reduced its use of fossil fuels and purchased energy by 53%, while increasing total production by nearly 64 percent over the same period. Currently the forest products industry meets nearly 60 percent of its own energy needs, producing nearly 43 percent of the nation's total self-generated electricity-more than any other manufacturing sector. Even so, the industry is one of the country's most energy intensive, ranking as the third largest user of fossil energy in the U.S. manufacturing sector (EIA, 2000).

The paper industry, is also emission intensive. For this Standard Industrial Classification (SIC) code, SIC code 26, the total energy-related emissions nation-wide is 31.6 million metric tons of carbon (MMTC). This represents 8.5% of all emissions in SIC codes 20-39. The main source of emissions is from net electric energy used by facilities (11.0 MMTC), followed by natural gas (8.3 MMTC), and coal (7.9 MMTC) as the top three. Paper and paperboard mills account for over 80 percent of the energy-related carbon emissions in the paper industry (EIA, 2000).

Energy and carbon dioxide (CO_2) conversion factors were used to present the total emissions due to energy consumption for the facilities, and the corresponding emission reduction due to the ECOs. The factors for electricity are for electricity production for the United States, and represent the current mix of generating facility types nation-wide. For electricity, 1.43 lbs of CO_2 per kilowatt-hour was used, and for natural gas 117 lbs of CO_2 per million Btu (RMI, 1999).

State of Illinois

Ranking as one of the state's top manufacturing industries, Illinois' forest products industry is a vital component of the state's economy. The industry employs 50,000 workers with an annual payroll of $1.7 billion (AFPA, 2001). Illinois' paper and wood manufacturing workforce represents 4.3 percent of the state's total manufacturing workforce (AFPA, 2001).

There are a total of 372 paper manufacturing facilities located in Illinois. Approximately 362 of these plants are involved in converted paper product manufacturing.

These plants generate total sales of $5.9 billion and make approximately $172 million in capital improvements per year. This segment employs 29,000 workers with a payroll of just over $1 billion per year (AFPA, 2001).

Plants Assessed

Overview

The ERC conducted energy assessments of ten paper and paperboard manufacturing plants in the Chicago metropolitan area between November 2001 and December 2002. To maintain plant confidentiality, plants are identified as Plant 1 though 10, as well as by their SIC code throughout this study. Most of these plants manufactured corrugated product, with the exception of one plant, Plant 6, which manufactured coated and laminated packaging papers and films. The specific energy using systems studied were the compressed air generation and distribution systems, process motors, steam boilers and steam distribution systems, lighting and heating, ventilation and air conditioning (HVAC) systems. Utility bills were collected and avoided costs calculated for each energy type.

The plants were evaluated over the course of one to four days, with visits normally scheduled on production days. For each assessment, plant personnel at all levels were interviewed, both formally and informally. Equipment operators, maintenance workers and supervisors, plant managers and general managers and when available, chief financial and executive officers and corporate energy managers were queried for information to better understand plant operations and policy. Only those recommendations that fell within or slightly exceeded company capital investment budgets and guidelines were fully investigated and incorporated into the reports. Additionally, ongoing measures such as compressed air leak reduction, steam leak reduction and high efficiency motor replacement were recommended only if the plant had no consistently maintained program of its own. If an opportunity had already been identified by the plant but not budgeted, it was incorporated; measures that a plant was currently implementing were not incorporated into the reports.

All of the plants assessed were located in Illinois; three plants were in the city of Chicago, and the remaining plants were in the surrounding suburbs of the city. These facilities ranged in size[1] from 76,000 square feet to 250,000 square feet, and employed between 100 and 225 workers. Seven of the facilities are part of larger national or multi-national firms. Further data for the included plants, including 4-digit SIC codes and operating hours, are presented in Table 1.

Energy Usage

Each of the ten plants in the study consumed both electricity and natural gas for powering primary manufacturing equipment, secondary support systems, and supplemental equipment. Energy usage among the ten plants varied greatly, and was highly dependant on the product produced, age and condition of equipment, operating procedures and production orders. Recent utility bills for a consecutive twelve-month period (including both energy and transportation providers) were collected and analyzed for each of the facilities. These data

[1] Plant size only includes main buildings of each facility, not outbuildings or parking lots.

were then translated into average cost per unit of energy and presented along with annual usage and cost numbers in Table 2.

Table 1. Plant General Data

	SIC Code	Annual Production (square feet)	Plant Size (square feet)	Operating Hours (hrs/year)
Plant 1	2650	6,000,000	235,000	4,798
Plant 2	2631	50,000,000	250,000	6,240
Plant 3	2621	Not Available	200,000	6,120
Plant 4	2677	Not Available	110,000	5,616
Plant 5	2653	75,000,000	180,000	4,992
Plant 6	2671	Not Available	76,000	7,368
Plant 7	2657	40,000 tons	220,000	6,624
Plant 8	2653	Not Available	160,000	6,600
Plant 9	2653	800,000	107,000	6,500
Plant 10	2650	850,000,000	150,000	6,000

Table 2. Plant Energy Usage and Cost Data

	Energy Usage (kWh/yr)	Unit Cost Of Energy ($/kWh)	Demand kW (kW/mo)	Demand Unit Cost ($/kW)	Gas Usage (MMBtu/yr)	Gas Unit Cost ($/MMBtu)	Total Energy Usage (MMBtu/yr)	Total Energy Budget ($/yr)
Plant 1	3,776,692	$0.047	1,102	$13.76	94,870	$6.82	107,760	$1,005,326
Plant 2	5,837,438	$0.037	1,102	$14.06	83,209	$2.57	103,132	$621,538
Plant 3	4,501,497	$0.064	933	$5.61	6,677	$7.52	22,041	$401,686
Plant 4	3,604,875	$0.063	877	$5.27	0*	$0*	1,057*	$281,449*
Plant 5	3,705,556	$0.063	777	$4.73	65,730	$3.91	78,377	$537,413
Plant 6	5,504,246	$0.055	1,056	$7.43	69,183	$5.42	87,969	$776,051
Plant 7	8,293,446	$0.056	1,498	$3.59	21,502	$7.47	49,808	$692,453
Plant 8	5,185,689	$0.064	869	$3.59	58,666	$3.16	76,365	$556,556
Plant 9	2,798,121	$0.065	555	$3.64	43,660	$2.47	53,210	$317,460
Plant 10	2,238,763	$0.067	436	$3.64	42,908	$3.45	50,549	$317,751
AVERAGE	**4,544,632**	**---**	**921**	**---**	**54,045**	**---**	**69,795****	**$549,421****
TOTAL	**45,446,323**	**---**	**9,205**	**---**	**486,405**	**---**	**629,211****	**$5,226,234****

* The plant had no natural gas using equipment, but did receive steam and heat from a district boiler. Quantity of steam and heat provided and amount paid for the heat were not available.
** Figures adjusted to exclude Plant 4.

Due to deregulation of both the electric and natural gas utilities in Illinois, all of the plants included in the study negotiated their electricity contracts, and most negotiated their natural gas contracts as well. Contracts vary between plants, some with lower usage (kWh) charges, but higher demand charges, and vice versa. Plant 1 had a natural gas cogeneration system on line, which was used to provide energy to the plant and steam to its production process. However for the base year, the generator was not in operation for seven months out of the twelve-month period. The plant was penalized with high stand-by demand charges as part of its cogeneration rider.

Major Energy Using Systems

There are several main energy using systems in pulp and paper manufacturing facilities. These include compressed air, electric motors, process steam, lighting, and heat. There were many similarities among the plants with respect to the types of energy-using equipment operated. All of the plants had a significant amount of compressed air and electric motors driving their operations, as well as lighting throughout the facility. Seven of the ten plants required significant amounts of steam in their processes. Six of these facilities had large boilers that provided steam, while the seventh facility, Plant 1, used its cogeneration plant, supplemented by a small boiler to provide the necessary plant steam. The total installed capacity for these major energy-using systems for each plant are presented in Table 3.

Table 3. Plant Major Energy Using Systems

	Compressed Air (total HP)	Motors (total HP)	Lights (total kW)	Boiler/Heating (Btu)
Plant 1	200	3,086	129	3,000,000
Plant 2	295	890	127	16,750,000
Plant 3	250	9,634	171	No boiler
Plant 4	285	740	62	Unavailable
Plant 5	300	1,460	188	24,254,000
Plant 6	150	2,386	45	1,350,000
Plant 7	215	2,889	191	18,675,000
Plant 8	150	2,101	150	40,200,000
Plant 9	250	1,405	98	16,738,000
Plant 10	150	1,970	85	14,645,000
AVERAGE	**225**	**2,656**	**125**	**15,068,000**
TOTAL	**2,245**	**26,561**	**1,246**	**135,612,000**

Compressed air. In the United States, compressed air systems account for 0.5 percent of energy-related carbon dioxide emissions. By improving the operation of industrial compressed air systems, facilities can provide energy efficiency improvements of 20-50 percent (OIT, 2002). Close observation of operations at the facilities and detailed questions to plant management revealed that compressed air is considered by many plant personnel to be a resource that costs little to operate and maintain. In addition, personnel believed maintaining compressed air systems to be difficult and fiscally inefficient. That is, purchasing additional capacity is more prudent than addressing false demand caused by excessive system leaks. Often problems with compressed air systems were "fixed" by increasing the operating pressure at the source in order to maintain the required end use pressure. A number of compressed air ECOs were found at nearly all of the plants surveyed. Nine of the ten plants had compressed air systems that offered significant opportunities for energy conservation and cost savings in leak reduction, outside air usage, reduction of compressor air pressure, energy-efficient nozzles, or a combination of the above measures. The notable exception to this was Plant 5, which recently installed a new compressed air system and was implementing a thorough leak mitigation program. The summary of compressed air savings opportunities is outlined in Table 4.

Table 4. Plant Compressed Air Savings Summary

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Demand Savings (kW/mo)	Demand Cost Savings ($/yr)	Total Cost Savings ($/yr)	Implementation Cost ($)	Simple Payback (months)
Plant 1	304,958	$14,332	64	$10,496	$24,828	$3,000	1.4
Plant 2	267,664	$9,904	43	$7,237	$17,141	$4,400	3.1
Plant 3	60,066	$3,844	10	$4,180	$8,024	$1,434	2.1
Plant 4	30,940	$1,949	11	$696	$2,645	$1,900	8.6
Plant 6	81,348	$4,473	11	$984	$5,457	$2,900	6.4
Plant 7	126,699	$7,094	19	$824	$7,918	$5,000	7.6
Plant 8	41,003	$2,624	6	$267	$2,891	$969	4.0
Plant 9	89,522	$5,819	25	$1,077	$6,896	$4,023	7.0
Plant 10	85,714	$5,745	14	$626	$6,371	$2,900	5.5
AVERAGE	**120,879**	**$6,198**	**23**	**$2,932**	**$9,130**	**$2,947**	**4.0**
TOTAL	**1,087,914**	**$55,784**	**203**	**$26,387**	**$82,171**	**$26,526**	**---**

Motors. This industry spends 2.6 percent of its overall operating costs to operate electric motor systems-higher than any other 2-digit manufacturing SIC. Motor system electrical costs could be reduced by 14 percent on average by simply factoring in energy efficiency and utility costs into motor purchasing or repair evaluations (OIT, 1999). Installed motor capacities varied at the plants surveyed. As with most industrial facilities, motors of varying load factors and efficiencies were found throughout the plants. In the event of a motor failure, many facilities use “stock motors” regardless of the motor size or efficiency when replacing faulty motors, even though premium-efficiency motors are available. Opportunities to improve motor efficiency were present at all ten plants. Replacing a standard efficiency motor with a premium efficiency motor can result in energy savings over the life of the motor, and can be readily evaluated using OIT’s MotorMaster+3.0 software. Premium efficiency motors were not purchased due to maintenance practices that do not emphasize motor efficiency, plant motor purchase practices, insufficient premium efficiency motors information and the low priority of energy efficiency decisions as compared to the high priority of minimizing production downtime.

Boilers/heating. Process heating for industrial facilities accounts for 17 percent of all industrial energy use (OIT, 2002). In the plants assessed, on-site boilers provided process heat. Several ECOs were discovered during these assessments. These included improving boiler combustion efficiency, using blowdown steam energy rather than live steam to preheat makeup feedwater, and installation of a stack economizer. For example, tuning the boiler at Plant 1 would raise the combustion efficiency at the plant from 78.4 percent to 80.9 percent, and result in natural gas consumption and cost savings. By using blowdown steam rather than live steam to preheat makeup water, Plant 1 could recover energy currently available, but discarded. Nearly 85 percent of the boiler blowdown energy could be recovered by piping the boiler blowdown to the existing flash tank/feedwater heater tank auxiliary system already in place (Dyer & Maples 1991, 9-14). By installing a stack economizer at Plant 5, waste heat from the boiler exhaust flue could be used to preheat combustion air and increase the efficiency of the boiler. For these recommendations, the implementation cost is higher than for other energy-using systems, but the resulting paybacks are still attractive. Boiler efficiency improvement opportunities for the applicable plants are presented in Table 5.

Table 5. Plant Boiler Savings Summary

	Total Energy Savings (MMBtu/yr)	Total Cost Savings ($/yr)	Implementation Cost ($)	Simple Payback (yrs)
Plant 1	7,462	$50,891	$37,536	0.7
Plant 5	1,854	$5,085	$13,727	2.7
AVERAGE	**4,658**	**$27,988**	**$25,632**	**0.9**
TOTAL	**9,316**	**$55,976**	**$51,263**	**---**

Steam leaks. With typical paybacks of less than six months, steam leaks resulting from piping or steam trap failures are a significant area of potential savings for an industrial facility. While the leaks found at the facilities were small, they represented a significant, consistent loss of energy. Plant operations and maintenance personnel were aware of specific leaks but did not place a high priority on fixing them. No matter the size of the leak, line pressure of the system at the point of exit, utility cost or maintenance rate, repairing a steam leak offered the best combination of high energy and cost savings at low cost at a specific location. The resulting simple paybacks are extremely attractive, with investment dollars being returned almost immediately. A summary of the leaks found and the associated savings and implementation cost is presented in Table 6.

Table 6. Plant Steam Leak Savings Summary

	Number of Steam Leaks	Total Energy Savings (MMBtu/yr)	Total Cost Savings ($/yr)	Implementation Cost ($)	Simple Payback (months)
Plant 1	4	1,561	$10,646	$900	1
Plant 2	4	3,339	$30,178	$900	1
Plant 5	6	2,911	$11,382	$1,350	2
Plant 9	13	3,206	$10,710	$2,925	4
Plant 10	7	1,469	$5,069	$2,100	5
AVERAGE	**---**	**2,497**	**$13,597**	**$1,635**	**1.4**
TOTAL	**34**	**12,486**	**$67,985**	**$8,175**	**---**

Waste heat. Industrial processes generate large amounts of waste heat energy that is then released into the atmosphere. Waste heat issues were identified at six of the plants surveyed. Plants 2 and 8 had scrap collection systems powered by fans that moved corrugated scrap through the plant. These systems used plant air, which was exhausted outside of the facility. To offset this air loss, makeup air was drawn into the plant and heated to the ambient temperature. By ducting outside air directly to the scrap collection positions, outside air would comprise the majority of the exhaust air. Consultation with a major manufacturer of air conveyance systems indicated that a 70 percent savings of heated air could be expected if this system were implemented. Plant 6 had high quality heat available from its incinerator that could be used to supplement the heat provided by its curing rooms and ovens, while Plant 7 was venting hot air from its compressors outside during the winter months, heat that could be ducted to the production floor. A listing of the savings and implementation costs associated with waste heat recovery recommendations is presented in Table 7.

Table 7. Plant Waste Heat Recovery Savings Summary

	Total Energy Savings (MMBtu/yr)	Total Cost Savings ($/yr)	Implementation Cost ($)	Simple Payback (yrs)
Plant 2	2,671	$30,066	$21,105	0.7
Plant 3	559	$56,185	$35,508	0.6
Plant 5	997	$2,754	$9,057	3.3
Plant 6	15,931	$86,345	$61,557	0.7
Plant 7	1,253	$9,358	$8,500	0.9
Plant 8	6,385	$17,131	$57,993	3.4
AVERAGE	**4,633**	**$33,640**	**$32,287**	**1.0**
TOTAL	**27,796**	**$201,839**	**$193,720**	**---**

Lighting. Lighting is often overlooked at industrial facilities, though it often uses as much as 10-20 percent of the overall electrical energy budget (BTP, 2002; EERE, 2002). All of the plants surveyed had inefficient lighting systems installed in the production, warehouse, and office areas. Several lamp types were repeatedly found, including T-12 fluorescent lamps with magnetic ballasts (both 4 foot and 8 foot), high intensity discharge lamps, and incandescent lamps. Most of the plants had considered retrofitting their lighting systems at some point, either using internal labor or contracting to an outside vendor. Significant savings opportunities were found in replacing existing lamps and ballasts with more efficient ones (such as T-8 or T-5 lamps with electronic ballasts), for all lamp types and using controls such as occupancy sensors and dimmers where appropriate. Though often with longer payback periods, lighting retrofits were often recommended for sections of the plants at a time, in order to spread out the investment cost. The summary of energy and cost savings, along with implementation costs for the plants is presented in Table 8.

Insulation. Insulating exposed steam pipes, valves, and/or tanks can result in natural gas and cost savings. It is important not only that surfaces be covered, but that the insulation is installed properly, and that insulation that has degraded over time be replaced. While the bare surfaces were small in terms of total area, the areas were directly responsible for significant heat losses. While installing insulation in some areas may be more difficult due to being located in hard to reach areas or near the ceiling, if installed properly, it is a one time event that will result in consistent energy conservation and savings. Five of the plants assessed had bare steam pipes, valves, and/or tanks, as well as places where insulation had never been applied or where the insulation had degraded over time. Degradation mainly occurred in areas where insulation was not properly wrapped or protected. For process heating and steam systems, 1.5 inch mineral fiber board insulation (R=3.0) is typically recommended for pipes, valves and tanks and evaluated using OIT's 3E Plus software. Listings of insulation energy and associated cost savings, as well as implementation costs, are detailed in Table 9.

Table 8. Plant Lighting Savings Summary

	Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Demand Savings (kW/mo)	Demand Cost Savings ($/yr)	Total Cost Savings ($/yr)	Implementation Cost ($)	Simple Payback (yrs)
Plant 1	245,670	$11,547	53	$8,657	$20,204	$71,260	3.5
Plant 2	22,303	$825	3	$563	$1,388	$3,057	2.2
Plant 3	208,604	$13,353	45	$3,025	$16,378	$59,444	3.6
Plant 4	52,611	$3,314	22	$1,391	$4,705	$31,710	6.7
Plant 5	273,557	$15,160	51	$2,115	$17,275	$85,625	5.0
Plant 6	172,694	$9,513	24	$2,096	$11,609	$35,754	3.1
Plant 7	75,278	$4,217	36	$464	$4,681	$21,512	4.6
Plant 8	409,979	$26,239	62	$2,676	$28,915	$76,995	2.7
Plant 9	265,613	$17,268	45	$1,654	$18,922	$52,443	2.8
Plant 10	7,666	$515	3	$129	$644	$2,361	3.7
AVERAGE	**173,398**	**$10,195**	**34**	**$2,277**	**$12,472**	**$44,016**	**3.8**
TOTAL	**1,733,975**	**$101,951**	**344**	**$22,770**	**$124,721**	**$440,161**	**---**

Table 9. Plant Insulation Savings Summary

	Total Energy Savings (MMBtu/yr)	Total Cost Savings ($/yr)	Implementation Cost ($)	Simple Payback (yrs)
Plant 1	517	$3,523	$4,516	1.3
Plant 5	405	$1,349	$471	0.3
Plant 8	1,342	$4,241	$5,892	1.4
Plant 9	877	$2,164	$5,153	2.4
Plant 10	496	$1,708	$2,582	1.5
AVERAGE	**727**	**$2,597**	**$3,723**	**1.4**
TOTAL	**3,637**	**$12,985**	**$18,614**	**---**

Results

Overall Energy Savings and Emission Reductions

The seven energy-using systems examined offer significant natural gas and electricity energy conservation and cost savings opportunities for all ten plants surveyed. Steam leak and compressor leak repairs demonstrated the best ratio of lowest implementation cost to projected savings with the shortest payback time. Other compressed air ECOs and boiler efficiency offer the next best set of savings numbers, with compressed air investments returning investment dollars in less than four months and boiler efficiency upgrades paying back in eleven months. The first-costs for the remaining recommendations are higher and the payback times significantly longer. It was also at this point that the plants cease to have the option of implementing the recommendations incrementally, allowing them to spread out the costs across one or more years. The recommendation for waste heat recovery was within the payback range of all ten plants assessed, but the first costs take up too large a portion or exceed the allotted capital investment budget. Lighting retrofits offer the least attractive combination of first costs, savings and payback. While lighting retrofits can be implemented incrementally, the long payback, significant commitment over time and potential disruption of plant operations all make for a unappealing combination. Annual energy savings and emission reduction totals by fuel type for all ECOs presented are listed by plant in Table 10.

Table 10. Plant Annual Energy Savings Summary

	Energy Savings (kWh/yr)	Demand Savings (kW/mo)	Nat. Gas Savings (MMBtu/yr)	Total CO_2 Reduction (tons)
Plant 1	550,628	117	9,540	951.8
Plant 2	289,967	46	6,010	558.9
Plant 3	268,670	55	1,519	281.0
Plant 4	83,551	33	0	59.7
Plant 5	273,557	51	6,167	556.4
Plant 6	254,042	35	15,931	1,113.6
Plant 7	201,977	55	1,253	217.7
Plant 8	450,982	68	10,534	938.7
Plant 9	355,135	70	4,083	492.8
Plant 10	93,380	17	4,644	338.4
AVERAGE	**282,189**	**55**	**6,631**	**589.7**
TOTAL	**2,821,889**	**547**	**59,681**	**5,509.0**

When considered as a group, the simple paybacks for the recommendations concerning seven of the ten plants fall within typical capital investment guidelines. With the exception of Plant 4, which purchased steam and heat from a non-utility supplier, all of the plants have opportunities to conserve both electricity and natural gas and realize cost savings. As a percentage of total energy budget, savings range from as little as 2.6 to 22 percent, with an average of 10.4 percent. The amount of emission reduction from primary energy input for all of the plants and all of the recommendations is 8 percent. Energy cost savings and implementation cost totals for all energy-using systems are presented by plant in Table 11.

Plant Opportunities and Available Tools

For improving overall energy efficiency and reducing energy costs at these plants, a holistic and proactive approach is encouraged. The DOE Office of Industrial Technologies (OIT) has programs and tools available to assist industrial facilities in undertaking energy conservation measures for the major energy using systems presented. This includes free software packages that are available to assess energy savings potential in areas such as compressed air, motors and pumps, steam, and insulation. These tools are available for download at the OIT website (www.oit.doe.gov). Using these tools requires the facility to invest some time and take a proactive, systems approach to energy use at the plant, but the overall savings can be significant. Though the management from the plants assessed during this program was presented with information about the OIT tools during the assessment, none had prior knowledge of the availability of the OIT tools.

Table 11. Plant Annual Energy Cost Savings and Implementation Summary

	Energy Savings ($/yr)	Demand Savings ($/yr)	Nat. Gas Savings ($/yr)	Total Cost Savings ($/yr)	% of Total Energy Budget	Implementation Cost ($)	Simple Payback
Plant 1	$25,879	$19,153	$65,060	$110,092	11.0%	$117,212	1.1 yrs
Plant 2	$10,729	$7,800	$60,244	$78,773	12.7%	$29,462	5 mos
Plant 3	$17,197	$7,205	$63,935	$88,337	22.0%	$102,618	1.2 yrs
Plant 4	$5,264	$2,087	$0	$7,351	2.6*	$33,610	4.6 yrs
Plant 5	$15,160	$2,115	$20,570	$37,845	7.0%	$110,230	2.9 yrs
Plant 6	$13,986	$3,080	$86,345	$103,411	13.3%	$100,211	1.0 yrs
Plant 7	$11,311	$1,288	$9,358	$21,957	3.2%	$35,012	1.6 yrs
Plant 8	$28,863	$2,943	$30,242	$62,048	11.1%	$164,569	2.7 yrs
Plant 9	$23,087	$2,731	$12,874	$38,692	12.2%	$64,544	1.7 yrs
Plant 10	$6,260	$755	$16,020	$23,035	7.2%	$71,143	3.1 yrs
AVERAGE	**$15,774**	**$5,462**	**$40,516**	**$57,154**	**10.4%**	**$82,861**	**1.4 yrs**
TOTAL	**$157,736**	**$49,157**	**$364,648**	**$571,541**		**$828,611**	**---**

* Figure takes only electrical savings into account

In order to best use the OIT tools, accurate plant data are necessary. Information for anything from the facility utility rates to the size and efficiency of the motor powering the compressed air system, and boiler operating temperatures and pressures are crucial to get the most out of these tools. A brief description of these tools is provided in the following paragraphs.

MotorMaster+3.0 is a motor management tool, which allows for comparing various efficiency motors, creating a record of maintenance for each motor, as well as predicting energy, savings, and environmental benefits of using high efficiency motors. The software has a catalog of over 20,000 AC motors, which is searchable by motor type and manufacturer. Additionally, this program, can assist in decreasing motor inventory and track motors that continually fail.

AirMaster+ is a compressed air software tool that assists in assessing the compressed air system in a comprehensive manner, including evaluating system upgrades. Each compressor within a facility is inputted, along with compressor operating pressure, airflow capacity, end uses, and control information. As with the MotorMaster+3.0 software, this tool also assists in the creation of a maintenance log, to record and track changes and problems with the system. Evaluating savings and effectiveness of energy efficiency measures is also feasible with this tool.

For steam systems, there are currently two available tools, the Steam System Scoping Tool 1.0c, and the Steam System Assessment Tool. These tools were designed to help facility managers assess savings from potential steam system improvements, as well as create a profile for the existing steam system; much like the AirMaster+ does with the compressor system. Plant conditions that are inputted into the facility profile will assist in calculating energy, cost, and emissions savings of potential improvements, as well as track the performance and maintenance of the steam system.

Finally, with 3E Plus, a Microsoft Windows® based software, evaluation of installing or improving insulation on exposed surfaces such as heat tanks and steam pipes can be done. While this program does not create a database of the pipes and surfaces, it is an important tool in determining the cost effectiveness of insulating and emissions reductions due to the resulting energy savings. The program is able to calculate the most economical thickness of industrial insulation for a given process, with the operating conditions, ambient temperatures, and surface properties as inputs.

In addition to the software tools available, the DOE OIT also has energy tips and case studies separated out by industry to assist manufacturers in investigating ECOs, and demonstrate realized savings from actual facilities.

Impediments, Barriers, and Accelerants to Implementation

Reasons vary when determining why energy conservation measures are not implemented or why efficiency improvement tools are not used. Among the reasons include: high paybacks associated with energy recommendations, the related implementation costs, and potential downtime to implement the recommendations. Of the ten plants surveyed, eight of the plants required paybacks of less than two years while five of the eight plants wanted returns of less than eighteen months. The time required to actually implement a project often seemed to be a factor in decision-making. Plant management and maintenance personnel indicated indirectly that projects that can be completed in a short amount of time have greater chance of being implemented than projects that are expected to take longer, even if the projects taking longer have better payback numbers. Projects that are either recurring or incremental in nature were viewed with skepticism. Competing for approval and funding with other capital expenditures was also seen as a deterrent to implementing the energy saving measures. However, certifications for ISO or QSO certification were given as reasons for implementing energy conservation measures.

The OIT software tools mentioned previously are readily available and supported, but in general are not in use at facilities due to plant personnel having insufficient product knowledge, lack of training, and the time required to set up the facility profiles in each of the programs. Time must be taken at the start, as the tools can only be as useful as the accuracy of the information entered. As part of a rigorous approach to energy conservation at a facility, these tools can increase the efficiency and productivity of a plant, and create a record of recurring problems or issues with the major energy using systems, thereby adding a modicum of predictability to plant maintenance programs. This can assist in not only reducing energy consumption, but also decreasing a facility's downtime.

Conclusion

The paper and paperboard industry, a subset of SIC 26, is an energy and emissions intensive industry that is growing at a steady rate. As fuel and operating costs continue to rise, the industry will continue to look for ways to increase its efficiency, raise profitability and reduce emissions, without large capital expense, resulting in a short payback period. Assessments of ten SIC 26 facilities in the State of Illinois demonstrated that there are several ECOs in the major plant energy-using systems alone. In Illinois, if the plants assessed implement the energy conservation measures identified, an average savings of electricity usage of 2.8 MWh/year and an average savings of natural gas usage of 59.7 MMBtu/year are attainable. Consequently, an estimated 5,509 tons of energy-related carbon dioxide emissions per year would be eliminated from the environment.

The Office of Industrial Technology has recognized and addressed the need for energy resources and has software and tools available at no cost to the user. However, the availability of these tools for assessing opportunities in industrial facilities is not well known and therefore the use of these tools in facilities has been relatively limited. None of the assessed plants were using nor had knowledge of the OIT tools prior to the energy assessment.

By following energy conservation recommendations, reviewing case studies, and using available software tools, any paper and paperboard manufacturing facility can work toward reducing energy consumption and increasing efficiency, thereby leading to a reduction in carbon dioxide emissions to the environment.

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