Energy Study in the Illinois Chemicals Industry

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ABSTRACT

With over $5 billion in annual sales in the state of Illinois, the well being of chemical processing plants[1] is important to the economy of the state of Illinois. By realizing lower energy costs and implementing strategies that lower energy consumption, these companies can become more competitive in the national and international markets, thus creating jobs and tax revenue. In the case of an economic downturn, these plants could avoid closure and job loss.

The chemicals industry was studied because of its importance to the Illinois economy and the opportunities for significant improvements in their utilization of energy resources. Chemical plants use great amounts of energy for heat and power in the manufacturing process and are considered to be "energy-sensitive." In the case of U.S. chemical processors, SIC 28, 19.1 MBtu are used for every dollar of value added. The lower the energy use, the better for profits and the less vulnerable the industry is to energy price shocks.

The Energy Resources Center (ERC) performed energy assessments at five chemical manufacturing plants within the state of Illinois through a grant from the Illinois Department of Commerce and Community Affairs (IL-DCCA). The chemical plants assessed varied from small to large to batch process to continuous process applications. The objectives of these assessments were to develop an understanding of chemical manufacturers' energy-related issues, to profile energy-usage, and to make recommendations for energy-using systems. The results of the findings from these audits and projected impacts to the industry are discussed in this paper.

Introduction

The approach ERC engineers used in identifying Energy Conservation Measures (ECMs) is based upon the techniques and objectives set forth by the Department of Energy's Office of Industrial Technology's (DOE-OIT) *Best Practices* program. DOE-OIT regards the chemicals industry, nationwide, as one of the premiere industries for improvement potential in energy usage. The Best Practices program is an initiative of DOE-OIT that offers tools to help industry improve plant energy efficiency, enhance environmental performance, and increase productivity.

During this study, engineers, through Oakridge National Laboratories, with expertise in compressed air, steam, and pumping efficiency provided both field support and data

[1] SIC 2819,2821,2865,2869. Unless otherwise stated, "Chemical industries or plants" will refer to these SICs.

analysis in order to ensure a robust investigation. Throughout this study, attention was focused primarily on motor driven systems, steam systems, and compressed air systems. ECMs were concerned with implementing controls or new technologies designed for optimizing energy-using systems or optimizing/modifying operations and maintenance practices.

The types and sizes of chemical plants assessed varied substantially from small to large to batch process to continuous process applications. For the purpose of this study, a batch process was considered an operation that had specific processing procedures that needed to be completed prior to the product being moved on to the next procedure. A continuous process was an operation in which the processes were seamless, i.e., raw material in and final product out without minimal batch process characteristics. The distinction between a batch process and a continuous process was important when making recommendations for motors and variable frequency drives. High efficiency motor retrofits, for example, were considered less compelling for a batch operation that might use various process motors only a couple hours per day versus a continuous operation that operates various motors on an uninterrupted basis throughout a shift.

Project Objectives

The primary objective of this project is to estimate how energy savings in chemical processing industries impact the economic development potential for the state of Illinois. Armed with this information, IL-DCCA can prioritize its efforts towards increasing the competitiveness of the chemical processors sector by reducing energy costs to manufacturers. Typically, the open market fails to prompt energy consumers to conserve energy. High first costs, underpriced environmental amenities, and lack of information all conspire to generate "market failure" in regards to energy conservation. State energy programs overcome some of the barriers to implementation and in so doing, benefit the economy not only in terms of energy reduction but also in terms of new and retained jobs and income. Currently, state programs to encourage energy efficiency are even more critical given deregulation and the potential loss of utility-funded conservation programs.

Other objectives of these assessments were to develop an understanding of the chemical manufacturers' conspicuous energy-related issues. By profiling the energy-usage characteristics of chemical manufacturers, ERC engineers were able to more effectively make recommendations for energy-using systems relevant to chemical manufacturing plants.

Industry Importance to Illinois

The most recent Bureau of Labor statistics show Illinois has 163 establishments that fall within the four SIC sectors within the Chemicals industry. (Table 1 and Table 2) When compared to other states, Illinois falls between second and seventh place, depending upon the SIC category. Sales made by Illinois chemical processing companies were valued at $5 billion in 1997 and represented 4 percent of total U.S. chemicals sales.

Table 1. Ranking for Illinois' 163 Chemical Establishments

	SIC 2819		SIC 2821		SIC 2821		SIC 2821	
	State	# firms	State	# firms	State	# firms	State	# firms
1	California	94	California	105	Texas	19	Texas	130
2	Ohio	55	Texas	65	Ohio	19	**Illinois**	**48**
3	Pennsylvania	52	**Illinois**	**65**	Louisiana	**13**	California	40
4	Texas	51	Ohio	59	South Carolina	12	Ohio	40
5	Louisiana	42	Pennsylvania	47	California	11	Pennsylvania	34
6	**Illinois**	**41**	Michigan	45	Michigan	10	New York	33
7	Tennessee	40	Georgia	33	**Illinois**	**9**	Louisiana	28

Table 2. North American Industrial Classification Corresponding to SIC Plants

SIC	NAICS	NAICS Meaning	Illinois Share	Illinois Rank
2819	.325998	All other misc. chemical product and preparation mfg	6%	4
2869	325199	All other basic organic chemical manufacturing	6%	3
2869	325188	All other basic inorganic chemical manufacturing	5%	3
2869	325120	Industrial gas manufacturing	4%	3
2819	325131	Inorganic dye and pigment manufacturing	9%	Top 3
2865	325132	Synthetic organic dye and pigment manufacturing	4%	5
2865	325110	Petrochemical manufacturing	6%	3
2819	211112	Natural gas liquid extraction	0%	
2865	325192	Cyclic crude and intermediate manufacturing	0%	
2869	325193	Ethyl alcohol manufacturing	0%	
2821	325211	Plastics material and resin manufacturing	0%	
2819	331311	Alumina refining	0%	
		Total	5%	

Energy Sensitivity - Impact on Profitability

Chemical plants use great amounts of energy for heat and power in the manufacturing process and are considered to be "energy-sensitive." In fact, Energy Information Agency numbers show that the SIC 28 sector had become 2.8 percent *less* energy efficient between the years 1985 and 1994.[2] The amount spent on all types of fuels and electricity accounts for between 5 and 8 percent of the value of Illinois chemical shipments. The national average is 5.5 percent. Table 3 demonstrates the results of an analysis on the twenty most "energy sensitive" industries nationwide. The chemicals industry ranks in the top five of industry with regards to "energy sensitivity."

[2] www.eia.doe.gove/emeu/mecs94/

Table 3. Energy Consumption Per Value of Dollar Added, U.S.[3]

SIC Industry Sector	Btu Per Dollar of Value Added	Energy-Sensitivity Ranking
29 Petroleum and Coal Products	113.1	1
26 Paper and Allied Products	43.5	2
33 Primary Metal Industries	39.8	3
32 Stone, Clay and Glass Products	22.7	4
28 Chemicals and Allied Products	19.1	5
24 Lumber and Wood Products	10.1	6
22 Textile Mill Products	9.5	7
20 Food and Kindred Products	6.7	8
30 Rubber and Misc. Plastics	4.2	9
34 Fabricated Metal Products	4	10
37 Transportation Equipment	2.4	11
25 Furniture and Fixtures	2.2	12
39 Misc. Manufacturing Industries	2	13
36 Electronic and Other Electric Equip.	1.7	14
35 Industrial machinery and Equipment	1.6	15
38 Instruments and Related Products	1.1	16
27 Printing and Publishing	1	17
23 Apparel and Other Textile Products	0.9	18
21 Tobacco Products	--	19
31 Leather and Leather Products	--	20

Often times, the company has no control over the price it pays for materials (commodities) but it can affect other labor and production costs such as energy. Thus, "Value Added" is the value of shipments less the cost of materials. In essence, Value Added is comprised of production and managerial costs as well as profit. In the case of U.S. chemical processors, SIC 28, 19.1 MBtu are used for every dollar of value added. The lower the energy use, the better for profits and the less vulnerable the industry is to energy price shocks. For example, the Printing and Publishing Industry (SIC 27) use only 1.0 MBtu per dollar of value added. Energy does not have a major impact on the printing sector's profits or value added. In an accounting sense, printers are relatively energy-insensitive. In contrast, Primary Metals Industries (SIC 33) use 39.8 MBtu per dollar of value added, implying that their profit may fluctuate to a larger degree due to variations in energy costs. At 19.1 Mbtu per dollar of value added, the Chemicals Industry is considered "energy sensitive."

Energy Usage Analyses

Energy load profiles at the five plants were developed in order to baseline electrical and gas fuel energy usage. Load profiles provided multiple sets of information to ERC

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[3] Source: Manufacturing Consumption of Energy, 1994, Table A23.

[4] Expenditure in millions of dollars. Based on Industry Statistics for States, 1997, and Manufacturing Industry Series, 1997 Census. Range is based upon Value of Shipments and Number of Plants.

engineers and architects in their effort to assess the energy usage and identify energy conservation measures (ECMs). First, it was important to know where and to what proportion of the total plant wide energy usage the various systems consumed energy. Second, by understanding which systems used the most energy, specific systems could be targeted for further investigation. Third, load profiles from individual facilities could be used to compare energy usage patterns at other facilities with similar processes and operational patterns. Fourth, they could provide verification of the engineering and energy savings calculations performed.

Electrical Energy Analysis

Summarizing the results of the load profiles developed for all five of Illinois chemical manufacturers assessed provides interesting results. Pumping accounts for the most significant load at 24 percent of the electrical energy usage. Agitator drives on reactor tanks account for an average of 18 percent. Pumps, agitator and compressors/blowers (motor driven systems) together account for more than 60 percent of the entire electrical energy load. Process cooling, depending upon the application, can range anywhere from a modest 6 percent to 32 percent (the average is 16 percent). Process cooling systems include energy to drive compressors, cooling tower fans, and cooling tower water pumps. The results, of the summary analysis, for the five plants are shown in Table 4 and Figure 1.

Table 4. Electrical Energy Usage Distribution Summary

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Average
Lighting/HVAC	16.3%	10%	22%	20%	28%	19%
Agitators	10.3%	12%	22%	16%	31%	18%
Process-Cooling	32.2%	7%	20%	17%	6%	16%
Pumps	29.7%	39%	20%	32%	0%	24%
Other	0.4%	2%	2%	3%	3%	2%
Compressed Air/Blowers	11.1%	30%	14%	12%	32%	20%
Total	100%	100%	100%	100%	100%	100%

The most revealing observation is that motor driven systems account for the highest proportion of the electrical energy usage at chemical manufacturing plants. Therefore, recommendations to save energy and utility costs were targeted through high efficiency motor retrofits, optimization of compressed air systems and the utilization of variable speed technology.

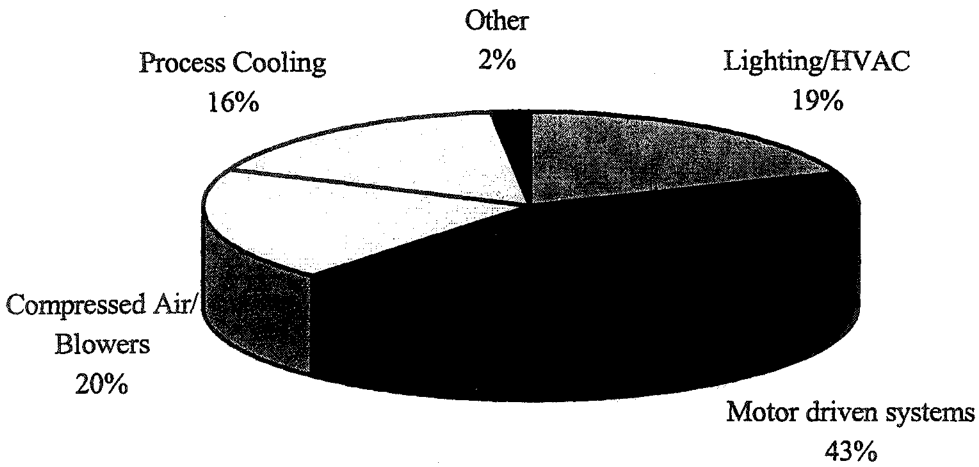

Figure 1. Summary Electrical Energy Load Profile of Five Chemical Manufacturers in Illinois

These results are consistent with the DOE's Motor Challenge program, which found that "almost 70 percent of the electrical energy used by manufacturing industries is dedicated to motor drives. The chemicals industry is the largest process user of motor driven electricity."[5]

Natural Gas Energy Analysis

Natural gas energy at the five chemical manufacturing plants is used for direct-fired process or environmental treatment applications including gas heaters, thermal oxidizers, and hot oil furnaces. However, the majority of natural gas is used to create steam energy in the boiler room heating. Plant 1, for example, consumed 100 percent of its gas energy in the boiler room with steam energy used for both process applications and heating. Figure 2 shows the results of the summarization of the gas-steam usage at the five plants surveyed. Losses generally refer to steam losses due to leaks, failed steam traps and piping distribution losses.

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[5] Energy Efficient Electric Motor Selection Handbook

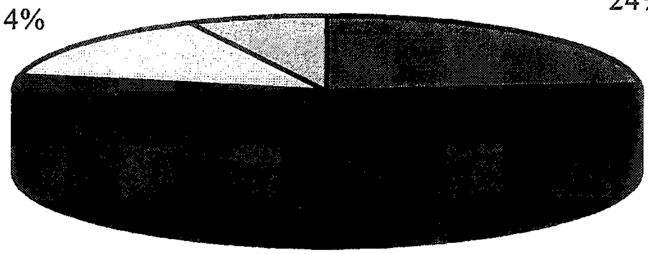

Figure 2. Summary Gas-Steam Energy Load Profile of Five Chemical Manufacturers in Illinois

The natural gas usage profiles provided similar impetus to focus ECM efforts on steam systems. Opportunities were identified for improving the combustion efficiency on boilers and gas-fired furnaces, use of heat exchangers, replacing failed steam traps, using infrared heating, and reducing base space heating temperature setpoints.

Energy Conservation Measures

This section of the paper presents and describes some of the ECMs that were identified in this study. The recommendations described represent some of the most compelling ECMs that were identified in this study.

Recommendation #1 Retrofit DC Drives with AC Vector Drives

Plant 2 used DC drives as agitators on several of their reactor tanks. DC drives, while effective in high torque loads, are inefficient. Newer AC drive technologies are available with significantly higher levels of efficiency. Vector drives can provide very accurate current control through the utilization of specialized power transistors to reduce speed while providing a high level of torque control.

Recommendation #2 High Efficiency Motor Retrofit

Plant 2, a continuous process facility, used several motors operating three shifts per day, seven days per week. An analysis for a motor retrofit was performed for all process motors greater and equal to 20 horsepower.

Recommendation #3 VFD on Boiler Feedwater Pump

The feedwater pumps at Plant 3 operated at a constant speed constantly. Based upon the variability in steam load requirements plantwide, a recommendation for variable frequency drives on those pumps was made.

Recommendation #4 High Volume- Low Pressure Blower

Current use of compressed air at Plant 4 for drying down reactor tanks following a steam cleaning operation was considered an abusive air demand. The initiating of tank drying produced a highly visible transient that upset system stability by typically initiating a cascade effect across all sections of the air system. The response of the system pressure during the high demand periods was a continual draw down of the air system. For this low-pressure air tank drying practice, it was recommended that low-pressure blowers be used instead.

Recommendation #5 Pressure Flow Controller

The main compressor at Plant 3 was operated with inlet valve modulation over a very wide range of operating capacity. Proper adjustment of the modulation point would result in a narrow range of modulation and essentially allow load/unload operation of control. With load/unload capacity control, the compressor would maximize the use of the large existing receiver volume and operate more efficiently.

Recommendation #6 VFD on Cooling Tower Fan

Currently, a single speed 25 horsepower standard efficiency motor continuously drives the cooling tower fan at Plant 3. When installed the unit was sized to maintain appropriate water temperatures during peak summer days. However, when the circulating air temperature drops, less airflow is required to pass through the evaporative chamber in order to attain the same cooling effect. A recommendation was made to install a VFD with a thermostat immersed in the tower water to provide speed control feedback to the drive.

Recommendation #7 Improve Furnace Efficiency

Thermal reactions in the reactor tanks at Plant 2 were performed through the use of hot oil. The plant employed two 7.5 MMBtu/hour furnaces to heat the oil for three process lines. The flue gas oxygen content of one of the furnaces was measured to be approximately 12 percent. When new these units were designed to burn at optimal oxygen content of 3 to 5 percent. It was recommended that at minimum these furnaces be manually tuned and at best be equipped with automatic combustion controls.

Recommendation #8 Infrared Heating in Warehouse

Plant 2 used greater than 50 percent of its steam to provide heat to a large warehouse adjacent to the production facility. Temperatures within the warehouse were maintained at 65°F throughout the heating season while being infrequently occupied for extended periods of time by production or warehouse staff. A recommendation was made to secure the space thermostats, reduce the temperature setpoints to 45°F an employ a heating strategy utilizing infrared heating.

Recommendation #9 Returning Condensate to Boiler

During construction at Plant 3, it was determined that returning condensate to the boiler room did not demonstrate a compelling economic benefit. Thus the entire condensate load at the plant is dumped. The exact decision criterion, at that time, was not available to ERC engineers for consideration, but was likely based upon a combination of misinformation, construction first cost considerations, and fuel costs at that time. Given the current steam load, it was estimated that a condensate load of 15,000 pounds per hour could be returned to the boiler room if the proper piping were in place.

Recommendation #10 Heat Exchanger for Dumped Condensate

An opportunity to take advantage of the thermal energy available in hot condensate was identified at Plant 1. Currently, a PH sensor and control valve operates to monitor silica leakage into the condensate return lines. When unacceptable levels of silica are detected in the condensate water, it is diverted and dumped into the sewage system. Sometimes long periods of time can go before this problem is remedied and condensate is redirected back to the boiler. In order to mitigate this practice a recommendation for capturing the energy in the hot condensate vis-à-vis a heat exchanger before dumping it was made.

Table 5 summarizes the budgetary implementation costs, dollar savings, energy savings and payback periods for the recommendations described above. Dollar savings were calculated based upon relevant electric utility rates and gas prices of $0.60 per Therm.

Table 5. Energy Conservation Measures and Savings[6]

Recommendation	*ECM cost*	*ECM savings*	*Energy Saving*	*Payback (years)*
#1 Retrofit DC Drives with AC Vector Drives	$102,431	$35,604	449,675 kWh	2.9
#2 High Efficiency Motor Retrofit	$123,654	$30,336	495,116 kWh	4.1
#3 VFD on Boiler Feedwater Pump	$9,800	$5,950	100,259 kWh	1.6
#4 High Volume-Low Pressure Blower	$16,500	$4,515	130,302 kWh	3.7
#5 Pressure/flow Control	$3,100	$732	22,405 kWh	4.2
#6 VFD on Cooling Tower Fan	$26,316	$8,098	135,885 kWh	3.2
#7 Improve Furnace Efficiency	$2,400	$40,021	66,701 Therms	0.1
#8 IR Heating	$67,837	$61,314	102,190 Therms	1.1
#9 Returning Condensate to Boiler	-	$70,884	118,140 Therms	-
#10 Heat exchanger for dumped condensate	-	$5,803	9,672 Therms	-

Conclusions-Impacts-Observations

Traditionally, energy savings realized by chemical processors were seen to negatively impact revenues of the utility industry. However, deregulation in the energy industry has

[6] Other opportunities included insulating steam and condensate pipes, repairing failed steam traps, cogeneration, and lighting retrofits in office areas.

introduced a new market dynamic to Illinois and other states. Utility companies are struggling to meet peak energy demands given current system capacities and supply availability. Thus, utilities are making every effort to reduce peak loads. Utility companies, are encouraging alternative energy strategies, especially in the industrial sector, such as conservation and distributed generation. In many instances, industrial customers are paid to curtail their energy use during critical periods. Instead of losing revenue from industrial customers who conserve energy, utilities are able to better balance the system and improve service and reliability.

Typically, required internal rate of returns on capital expenditure projects often place a limit on the implementation of energy projects. State energy programs can assist in overcoming some of the barriers to implementation; and in doing so, benefit the economy not only in terms of energy reduction but also in terms job retention and income. Currently, state programs to encourage energy efficiency are even more critical given deregulation and the potential loss of utility-funded conservation programs.

At the time of writing this paper, at least one of the chemical plants surveyed in this study (Plant 4) was in the process of submitting proposals in response to a statewide RFP from the IL-DCCA for energy improvements in the chemical industry. That plant has decided that regardless of the level of funding that would be received, they will implement those projects that demonstrate paybacks of less than two to three years. In the event that they would receive matching funds, projects that demonstrated extended payback periods (five to six years) would become more compelling. In the instance of this plant, those recommendations include lighting and boiler controls.

As an afterthought to the completion of the report deliverables, consideration was given to reassessing dual-fuel capabilities. Historically, No. 2 fuel oil has been used primarily as backup for natural gas in dual-fuel capacities. Given the current energy cost escalation for natural gas, No. 2 has emerged as a viable as an alternative fuel option.

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