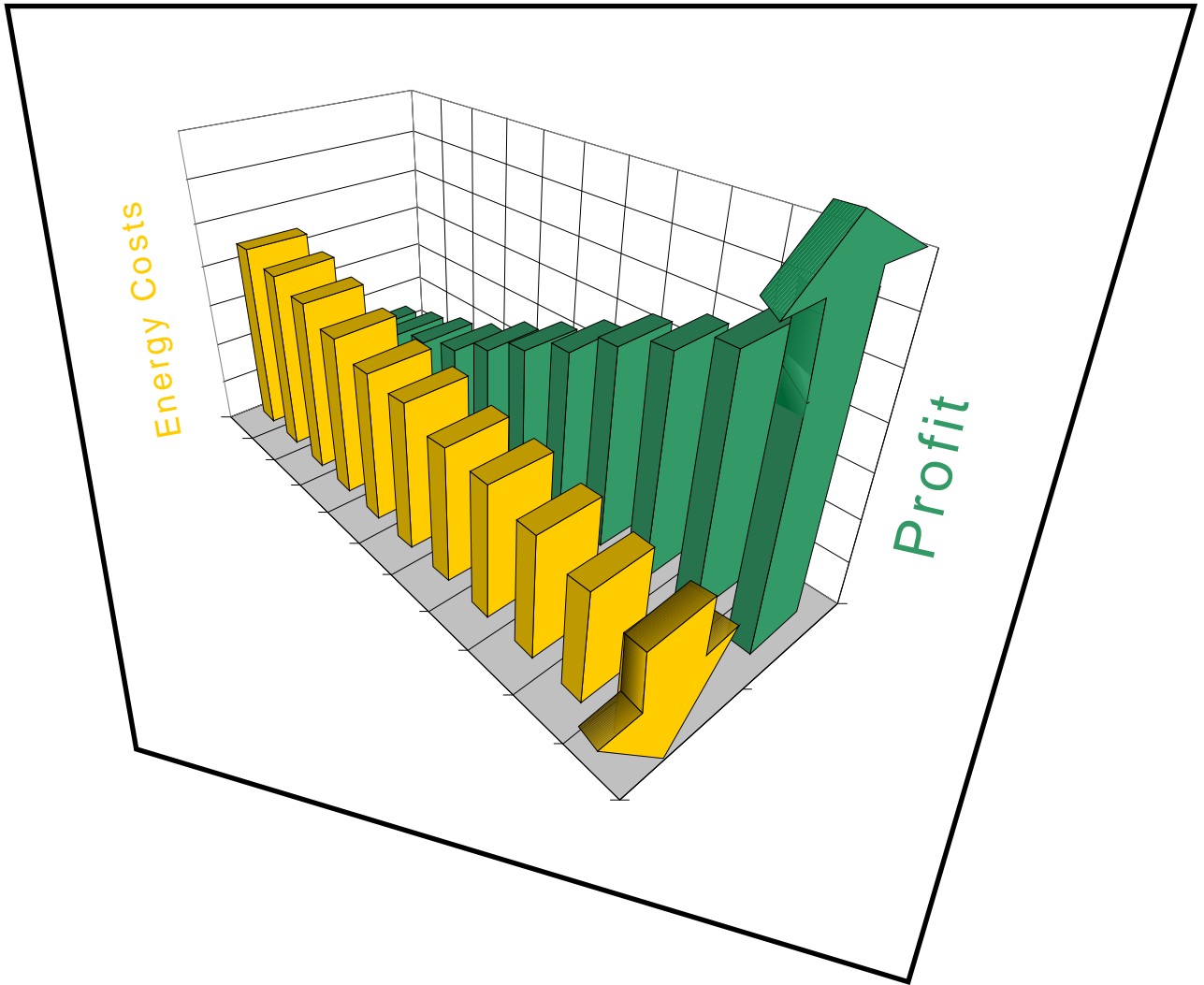


Reducing Energy Use Within Your Plastics Plant



How and Why

By
Illinois Department of Commerce and Community Affairs
Department of Energy and Recycling

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APPENDIX A

Saving Energy Equals Increased Profits

The plastics industry is an energy intensive industry. Approximately 3 percent of total annual expenditures are for energy costs required to operate everything from plant production equipment to office lighting. Any increase in efficiency within a plant will decrease the total cost for energy, which will increase profitability of the company. This is very important since the plastics industry is a high volume, low margin industry (after-tax profit is estimated at 3-4 percent of gross revenues).

Managing energy costs is no different than any other type of cost management. The required information is listed below:

- What are my fixed costs?
- What are my variable costs?
- Where can I save money?
- How many capital dollars are required to increase the efficiency of the plant?
- What is the rate of return (ROR) on the investment?

This handbook answers those questions for you. It tells you the importance of understanding your energy use and how to determine the baseline of your plant. It explains the areas within your plant where you can look for savings. It also provides example calculations of some of the most popular energy conservation opportunities (ECOs). Perhaps the best section of the handbook is case studies. Here, actual implemented energy conservation opportunities are presented and discussed.

Remember energy savings equal greater profits.

This handbook was prepared by the Energy Resources Center at the University of Illinois at Chicago under a grant from the Department of Commerce and Community Affairs (DCCA)

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How to Use This Handbook

The purpose of this handbook is to provide energy conserving ideas that can be implemented within your plant. Some energy conservation opportunities (ECOs) require extensive capital expenditures, while others require no or very low startup costs and can be implemented immediately.

Each section of this handbook describes an energy using section of your plant followed by ideas on how to reduce your energy consumption through ECO implementation or improved maintenance. Each section also demonstrates relevant examples showing energy saved and economic payback for all pertinent ECOs.

These sections present the material in a very user-friendly format. After all, the purpose is for you to start saving energy immediately. Also included in each section are real world examples of energy savings and corresponding economic paybacks. There is even a section that describes actual ECOs that have been implemented within plastic manufacturing plants in the state of Illinois. Finally, a section on impacts of electric deregulation describes what you can expect in the future and how to prepare for impending selection of an electric utility provider.

Overview of the Energy Audit Process

An energy audit provides information about value added (cost) to the plastic parts we manufacture and can point us to ways of reducing that cost, thereby increasing profits. In the plastics industry, some of the major users of energy are:

- Air compressors
- Production equipment (thermoformers, injection presses, etc.)
- Lighting
- Motors
- Heating, ventilating and air conditioning

Through an energy audit, you can accurately determine what percentage of your monthly energy is utilized by each category. The first step in this process is to understand how you get charged for energy, which is based on type of fuel used.

Understanding Your Utility Bills

Electric Utility Bills

Electric bills are often confusing; however, there really is no reason for the confusion. Basically, electric bills contain three sections:

Energy Demand (kW)-This is the amount of electric capacity the utility must provide you so your plant can operate. Usually the demand is actually a maximum demand for the given month. There is a charge for this demand per kW per month and different months might have different rates (an example of a ComEd rate is shown in appendix A).

Energy Usage (kWh)-This is the amount of power actually consumed during the operation of the plant. It is the product of the power (kW) of all the installed systems and number of operating hours in the month. There is a charge for this usage (per kWh), which can be constant, vary by time of day or vary based on total number of kWh used in a given month.

Other Costs-All other costs are lumped into this category. They include customer charge, fuel adjustments and a myriad of tax charges that are proportional to the amount of kWh used per month.

Natural Gas Utility Bills

In the case of gas utility bills, the type of data is similar. Your bill will include charges for the following:

- Amount of gas used, measured in Therms, cubic feet, or MMBtu
- Gas supply charge is the monthly average cost per Therm or MMBtu of natural gas.
- A distribution charge may also be incorporated as part of, or in addition to, the basic charges.

Calculating Your Consumption

The following table should be used for baselining and tracking your year to year energy consumption. To use this information, enter the appropriate information and determine the percent difference from year to year. If you begin to see major changes, without having applied any energy conservation measures, you should check to ensure that your utility rates have not changed or that processes are being used correctly. You may also use this table to measure the savings demonstrated by implementation of ECOs.

Table 1: Energy Use Table

Electricity							Gas or Oil		
Month	Energy Use (kWh)			Demand (kW)			Units =		
	Last Year	This Year	% Diff	Last Year	This Year	% Diff	Last Year	This Year	% Diff
Jan									
Feb									
Mar									
Apr									
May									
Jun									
Jul									
Aug									
Sep									
Oct									
Nov									
Dec									
Total									

Table 2: Energy Costs Table

Electricity							Gas or Oil		
Month	For (kWh) Used			Demand Charges			For Fuel Used		
	Last Year	This Year	% Diff	Last Year	This Year	% Diff	Last Year	This Year	% Diff
Jan									
Feb									
Mar									
Apr									
May									
Jun									
Jul									
Aug									
Sep									
Oct									
Nov									
Dec									
Total									

Energy Conservation Opportunities

Lighting Opportunities

Because of the large amount of energy consumed by lighting within plastic manufacturing plants and the fact that most plants operate multiple shifts, upgrading lighting systems can yield immediate energy savings and reduce your energy bills.

Lighting also influences the way people feel, work, and interact and can have a profound affect on productivity. The particular tasks performed at the many different workstations throughout a plastics plant should determine the quality, amount, and type of light installed. Different lighting levels are required for various tasks in the plant, the office and outdoor security and parking. These levels are recommended by the Illumination Engineering Society and are summarized in the following table.

Examples of Recommended Lighting Levels	
Lighting Level Range (footcandles)	Task Area
5	Outdoor Walkways
5-10	Dining Areas
10-20	Lightly Used Office Areas
20-50	Typical Office Work
50-100	More Demanding Tasks (Machine Shop or Office)
100-200	Very difficult Visual Tasks-Low Contrast Small Size

Source: Based on IES recommendations, IES Handbook.

How can you save lighting energy? First conduct a ‘walk through’ lighting audit. Count all of the different fixtures and lamp types in and around the plant (don’t forget the lights outside). Use a light meter to determine the existing light levels throughout the plant and determine if you have enough light. Talk to people to determine if there are specific problems such as glare or if the light level is too bright or too dim.

There are Three Major Ways to Save Lighting Energy...

- Install automated lighting controls
- Reduce light levels wherever there is more light than is needed
- Install more efficient lighting or controls

Turn off Lights When They Are Not Needed

Automated lighting controls include timers that turn the lights off when they are not needed. Typical areas where lights may be controlled include office lighting, parking lighting and any portion of the plant that is not occupied full time (perhaps the shipping/receiving area).

EXAMPLE:

Lighting in the shipping area of a small plastics manufacturing plant costs \$3,500 per year. Half of the cost could be saved by turning the lights off during the second shift when the area is idle. This measure can be automated by installing a digital timeclock.

First Year Savings	\$1,750
Timeclock Cost (installed)	\$1,100
PAYBACK (YEARS)	0.63 (7.5 months)

Use Natural Light

Using daylight as a source of illumination offers a tremendous potential for energy savings. Lighting levels can be reduced and often eliminated in areas with skylights or large windows.

To be effective, this requires a dimmable lighting system that is linked to the ambient lighting levels by means of a control photocell.

Use Occupancy Sensors and Other Lighting Controls

Occupancy sensors (infrared, capacitance, or ultrasonic) can be used to ensure that lights are turned off when a room or other section of the plant is unoccupied. Among the best places to use occupancy sensors are private offices, conference rooms, restrooms, and storerooms.

Other Automated Lighting Controls

Intermediate systems that are more elaborate than simple timers, but less expensive and complex than an Energy Management System (EMS) are available. Clock pin timers or photocells are useful for controlling parking lot lights or other exterior lights. New solid-state electronic photosensors combine long service life with accurate daylight sensing to yield significant energy and maintenance cost savings.

Disconnect Unused Ballast

If fluorescent lamps are removed but their ballast is not disconnected, the ballast will continue to use electricity when the fixture is energized. A ballast for two 40 watt lamps will use 6.5 watts. For maximum energy savings, always disconnect the relevant ballast when removing lamps.

Task lighting

Poor lighting of a workspace wastes energy. Task lighting should be considered as a means of reducing lighting load and increasing savings.

Relamping of Existing Fixtures-Example of Potential Savings-Lighting Retrofits

The following table shows the benefit of retrofitting 50-four lamp T12, fluorescent fixtures with T8 lamps.

SUMMARY: YEARLY ENERGY AND DOLLAR SAVINGS, IMPLEMENTATION COST AND PAYBACK								
Replacing T-12 Fluorescent Lamps + Magnetic Ballasts with T-8 Fluorescent lamps + Electronic Ballasts								
200 lamps @ [4 Lamps/Fixture]=50 Fixtures								
LAMP TYPE [fluorescent]	OPERATION [Hours/Year]	TOTAL NUMBER OF FIXTURES	TOTAL LAMP NUMBER	LAMP WATTAGE [watts]	LAMP WATTAGE [kilowatts]	BALLAST CORRECTION FACTOR	POWER CONSUMPTION [kilowatts]	ENERGY CONSUMED [kilowatt-hour/year]
T-12, 40 W	4160	50	200	40	0.04	1.2	9.6	39,936
T-8, 32W	4160	50	200	32	0.032	1	6.4	26,624
Yearly Energy Savings							13,312	[kWh/year]
Yearly Dollar Savings [for Energy]							\$908.89	
Implementation Cost (Includes labor)							\$4,658.50	
Payback [years]							5.1	

This example illustrates the savings potential of new lighting in a plastics plant operating two shifts, five days per week. Energy savings of 13,312 kWh/year would yield a dollar savings of \$909/year. This lighting investment would payback after five years.

If a plant operates three shifts, five days per week, the savings are even more apparent as depicted in the following table. In this example, the investment would payback after four years. This is summarized in the lighting retrofit table on the following page.

Maintenance

Proper lamp maintenance (dusting and cleaning) is essential to maintain proper lighting levels and should be a serious consideration when implementing any lighting energy conservation opportunity.

SUMMARY: YEARLY ENERGY AND DOLLAR SAVINGS, IMPLEMENTATION COST AND PAYBACK								
Replacing T-12 Fluorescent Lamps + Magnetic Ballasts with T-8 Fluorescent lamps + Electronic Ballasts								
200 lamps @ [4 Lamps/Fixture]=50 Fixtures								
LAMP TYPE [fluorescent]	OPERATION [Hours/Year]	TOTAL NUMBER OF FIXTURES	TOTAL LAMP NUMBER	LAMP WATTAGE [watts]	LAMP WATTAGE [kilowatts]	BALLAST CORRECTION FACTOR	POWER CONSUMPTION [kilowatts]	ENERGY CONSUMED [kilowatt-hour/year]
T-12, 40 W	6240	50	200	40	0.04	1.2	9.6	59,904
T-8, 32W	6240	50	200	32	0.032	1	6.4	39,936
Yearly Energy Savings							19,968	[kWH/year]
Yearly Dollar Savings [for Energy]							\$1,129.67	
Implementation Cost (Includes labor)							\$4,658.50	
Payback [years]							4.1	

Building Envelope

Your building's envelope is comprised of the windows, exterior doors, walls, foundation, floor, roof and possibly skylights. The envelope can be considered a barrier between your controlled indoor environment and the ever-changing outdoor environment. There are several ways to minimize heat losses in cold weather and heat gains in warm weather. The overall benefit to the plastics plant is to reduce heating, ventilation and air conditioning (HVAC) costs through the following practices:

- Reduce heat transfer in building envelope
- Stop infiltration through openings
- Control sunlight

Maintenance Opportunities for Savings

Reducing heat transfer losses can save energy. Many changes are inexpensive and relatively easy to implement.

Caulking

Any crack or gap in the building envelope should be sealed. Any old, dried caulking should be removed and replaced (for example, around windows). Other places that may need sealing include:

- Windows and door frames
- Where walls meet foundations
- Gaps in the foundation
- Where walls join at corners
- Where any pipe or electrical conduit enters the building
- Around window air conditioners (usually a big cause of air leakage)
- Around chimney flues from the furnace or boiler

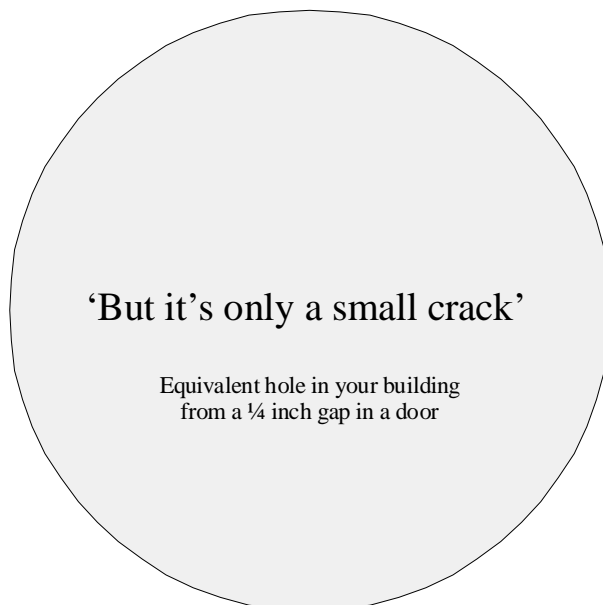
For small cracks, use a good quality (acrylic) caulk. Properly applied, these caulks are very long lived. For larger gaps, use 'expanding foam' insulating materials. Masonry cracks will require cement.

Remember, it may seem like a small opening, but just a ¼ inch gap in a standard 7 foot door/door jamb interface has an area of 20 square inches. It is equivalent to having a hole in your building the size of the figure on the following page.

Weatherstripping

Doors and windows should have proper weatherstripping as a barrier to insulation. Replace any worn or loose weatherstripping on all doors and windows. Install some where it has been omitted. Remember, doors and windows should close tightly. If necessary, repair or replace door jambs and window frames as needed to insure good operation and effective barrier to infiltration.

Also, broken or cracked windows are a safety hazard and drive up your energy bills. So do missing panes of glass. Make necessary replacements to all compromised window, as soon as possible.



Other Opportunities for Savings

Insulation

Adding insulation to your building is an effective way to increase your building's resistance to heat loss and heat gain. In winter, new insulation acts to reduce your heating bill. If your facility is air conditioned, new insulation cuts your air conditioning costs.

Before insulating, consider these tips:

- Assess condition of existing insulation to determine if adding insulation or replacing insulation is the best investment. Sometimes insulation (especially in roofs) has been so severely compromised due to water that replacing is the best solution.
- Do not add a vapor barrier if you already have one. This will cause condensation in the insulation or building structure.
- If you have a lot of heat producing equipment, adding insulation will raise the internal temperature and either increase air conditioning costs or decrease the level of comfort for employees. These must be considered and compared to the cost savings by adding additional insulation.

Insulation must meet state and/or local requirements for fire resistance and other properties. Adding insulation is a great way to save energy and money. Costs can be considerable, but paybacks are often short. The table on the following page demonstrates the R-value of some common insulation materials.

Window Replacement

Single pane windows conduct a significant amount of heat. The R value of a typical single pane window is low (0.9). Storm windows and solar films help to increase the resistance to heat gain/loss. Installing new windows offers other energy saving options. Double pane, low emissivity ('low E') windows offer R-values of two to eight times higher than older standard units. Paybacks are typically long so it is difficult to justify new windows from the standpoint of

energy alone. However, when remodeling, new windows may be justified as part of plant-wide energy awareness.

Window treatments are also helpful in reducing heat loss/gains through windows. Everything from utilizing movable blinds to planting deciduous trees can help save energy.

R Value of Some Insulation Materials

Material	R Value per inch of thickness
Fiberglass loose fill	2.5-3.0
Mineral fiber loose	2.5-3.0
Mineral fiber blanket	2.5-3.0
Cellular glass board	2.8
Perlite board	2.8
Fiberglass batt	3.0-4.0
Cellulose loose fill	3.1-3.7
Mineral fiber board	3.5
Polystyrene molded bead board	3.6
Fibrous glass board	4.0
Polystyrene foam board	4.2
Polystyrene extruded	5.0
Polyurethane foam board	6.3
Polyurethane foamed in place	6.7
Polyisocyanurate foamboard	7.2
Phenolic foam board	8.3

Heating, Ventilating and Air Conditioning (HVAC)

Heating, ventilation and air conditioning equipment (HVAC) is used to maintain the temperature and humidity in the office and plant areas. These areas are usually conditioned with separate equipment and the plant may not be air conditioned due to the excessive waste heat from the manufacturing processes.

However the plant and office are conditioned, energy saving opportunities exist by controlling the temperature and operating characteristics of the systems.

Reducing Building Temperature

Lowering thermostat setpoints in the winter and raising them in the summer can lead to HVAC savings. Care must be taken to balance energy savings with employee comfort, since comfort and productivity are very closely related. People have adjusted to lower temperatures by wearing sweaters or other layered clothing.

The following table demonstrates energy savings by reducing thermostat setpoint.

Percent Savings from Temperature Reduction

Heating Degree Days	Degrees Reduced on Thermostat			
	3 °F	5 °F	7 °F	10 °F
1000	15%	26%	36%	51%
2000	14	24	33	47
3000	13	22	31	44
4000	12	20	28	40
5000	11	18	25	36
6000	10	16	23	33
7000	9	14	20	29
8000	8	13	18	25
9000	6	11	15	21
10000	5	9	12	18

In the summer, setpoint temperatures can be adjusted with outside temperature. For example, on an 88 °F day a thermostat setting of 74 °F may be adequate to provide comfort. On a 98 °F day, a 74 °F temperature may seem too cold. The thermostat could be adjusted to 76-77 °F and still provide adequate indoor comfort with some energy savings.

A constant setback of 3 °F in the winter and set-forward in the summer can yield energy savings in the range of 8-20 percent.

Degree Days

A degree day is defined as the difference between 65°F and the average of the high and low temperature in a given day. The higher the number, the more energy will be used in the heating and cooling of your facility. In the winter, degree days are called heating degree days. Conversely, in the summer degree days are called cooling degree days.

Using a Temperature Setback Strategy During Unoccupied Hours

With virtually no exceptions, you will save energy by reducing the thermostat setpoint during unoccupied hours. The office is usually on a separate system and should use a setback strategy. If your system does not already have a programmable thermostat, one can be purchased and installed at a very low cost. In fact, this conservation opportunity usually pays back within a year after installation.

The following table demonstrates approximate energy savings by implementing a setback strategy. This is followed by an example of energy savings through use of a programmable thermostat.

Approximate Percent Savings from Setback

Degree Days	Setback Temperature		
	60	55	50
1000	13%	25%	38%
2000	12	24	36
3000	11	22	33
4000	10	20	30
5000	9	19	28
6000	8	16	24
7000	7	15	22
8000	7	13	19
9000	6	11	16
10000	5	9	14

EXAMPLE:

A small manufacturer of injection molded parts installed a programmable thermostat in the office and plant to reduce temperatures during unoccupied hours (nights and weekends). The thermostat had a manual override in case the plant needed to operate extra hours. Electric and natural gas savings worth \$2,170 occurred in the first year. The installed cost of the equipment was \$560.

First Year Savings	\$2,170
Thermostat Cost (installed)	\$560
PAYBACK (YEARS)	0.26 (~3 months)

Other considerations

Consideration should be given to mitigating energy losses. Exhaust fans should be used only whenever absolutely necessary, since in many circumstances we exhaust air that we have paid to condition. Also, pressurization between the plant and office environments should be controlled to minimize transferring conditioned air to typically unconditioned plants.

Generally purchasing and installing high efficiency HVAC equipment is not economically favorable. However, when existing systems must be replaced, consider purchasing the highest efficiency equipment available.

Boilers/Chillers

Boilers and chillers are typically thought of as HVAC equipment. In a plastics plant, boilers and chillers often provide process heating and cooling and therefore, they are described in this section.

Heating Systems (Boilers)

The heating load within your plastics plant is made up of comfort and process heating. These demands are typically met with either a boiler, furnace or both.

There are two places where inefficiencies can affect the operation of your heating plant:

1. At the generator (boiler or furnace)
2. Within the distribution system

The following energy conservation opportunities can reduce heating costs within your plant:

- Tune up the boiler or furnace
- Insulate all piping and tanks (whether using steam or hot water)
- Repair steam leaks (if applicable)
- Repair steam traps (if applicable)

Boiler Tuning

Over time, the combustion components of your boiler or furnace will degrade, causing greater amounts of fuel to be burned to provide the same heating benefit. This is an inefficiency that can be fixed relatively easily. A boiler repair person can test your combustion efficiency, tune the firing components (selecting the proper fuel/air mixture), and inspect and clean the heat exchanger surfaces, thereby improving your overall efficiency. The following table demonstrates the magnitude of savings available by improving your boiler efficiency to 80 percent. You can see if you have let your boiler efficiency degrade significantly (15 percent or more), significant savings are available.

Available Savings by Increasing Boiler Combustion Efficiency to 80 Percent

Fuel Cost (\$/year)	Initial Efficiency (%)				
	55	60	65	70	75
30,000	\$9,375	\$7,000	\$5,625	\$3,750	\$1,875
50,000	15,625	12,500	9,375	6,250	3,125
75,000	23,438	18,750	14,063	9,375	4,688
100,000	31,250	25,000	18,750	12,500	6,250
200,000	62,500	50,000	37,500	25,000	12,500

Typically this type of energy conservation opportunity pays back in less than one year.

If you just want a combustion test conducted, your gas and/or oil supplier may provide this test for you at no or a nominal charge. Should they be unable, contact your state energy office for a list of recommended combustion technicians. Another source is your local Yellow Pages under “Combustion Controls,” “Boiler Manufacturers,” or “Boiler Cleaning and Repair.”

Insulation

Bare or poorly insulated heating pipe wastes a lot of energy. Usually this energy is lost as undistributed heat in a ceiling or crawlspace. Fortunately, insulating pipe and tanks is relatively easy and the paybacks are very favorable.

The approximate dollar savings for insulating hot water pipe with one inch of insulation is \$1.50-2.50 per foot of pipe (\$2.00-\$4.00 for steam).

In addition to pipes, many plants have condensate tanks that are uninsulated. This wastes energy that must be added once again by the boiler. Average cost of insulating a tank is \$1.00 per square foot and can yield a savings of \$0.50-\$3.00 per year.

Typical installed costs for insulating pipes is presented in the following table followed by an example of implementing this energy conservation opportunity.

Cost to Insulate Pipe (Per Foot) with One Inch Fiberglass Insulation

Pipe Size (inches)	Total Cost
1	\$2.85
1 ½	3.25
2	3.68
2 ½	3.94
3	4.42
4	5.06

EXAMPLE:

A small plastics plant had 250 feet of three-inch uninsulated hot water pipe. One inch of fiberglass insulation was installed at a cost of \$1,105. At an average savings of \$2.25 per foot, the manager of the plant estimated a savings of \$563.

First Year Savings \$563

Insulation Cost (installed) \$1,105

PAYBACK (YEARS) 2.0 years

Note: Steam traps should not be insulated, nor should the first six feet of condensate piping following a trap.

Steam Traps and Leaks

Most plastic manufacturing plants that use steam do not have a rigorous steam trap maintenance program. A steam trap is used to prevent steam from entering the condensate lines which is a waste of energy. Being a mechanical device, they require service. Approximately 10-15percent of traps will fail every year. Quantifying savings is difficult; however, there is no doubt energy is being wasted by a failed trap.

Traps are typically tested using high precision digital thermometers or highly sensitive ultrasonic listening devices. Temperatures and sounds tell a great deal about the condition of steam traps. For example, a thermometer can be used to test the temperature up and downstream of the steam trap. If the temperature downstream of the steam trap is lower with intermittent swings up and down, this indicates the trap is operating properly. If the downstream temperatures are steady, however, the trap has failed. If the trap is cold, the trap has failed in the 'closed' position.

Listening to the sounds the trap makes can also indicate the relative condition of the trap. The table on the following page indicates a few operating sound scenarios.

Operating Sounds of Various Types of Steam Traps

Trap Type	Sound When Operating Properly	Sound When a Trap Failure Has Occurred
Disc-type (impulse or thermodynamic)	Opening and snap-closing of disc	Rapid chattering of disc as steam blows through
Mechanical-type (bucket)	Cycling sound of the bucket as it opens and closes	Fails open: sound of steam blowing through. Fails closed: no sound
Thermostatic-type	Sound of periodic discharge on medium to high load; possibly no sound if light load, throttled discharge	Fails closed: no sound

Cooling Systems (Chillers)

Chillers may be used in a plastics plant for either comfort cooling or part of the production process. Either way, there are some considerations to insure the costs of operating the chiller plant are as low as possible.

Chillers should be properly maintained per manufacturers' specifications including annual inspection of the heat exchangers.

Chillers should not be operated at less than 50 percent of rated load. The chiller efficiency drops off significantly at low loads and creates the need for hot gas bypass. If there is a need to operate at low loads, it is economical to install a small chiller to accommodate this load.

If your plant uses steam year round and has a significant cooling load, the use of absorption chillers may be useful at reducing utility costs. Absorbers use heat energy to drive the refrigerant cycle and do not use controversial CFC refrigerants. Newer systems can provide heating and cooling with relatively high efficiencies.

For comfort cooling purposes, evaporative cooling uses less than one-fourth the energy of vapor-compression chillers. Though the cost of an evaporative cooling system may be higher than a vapor-compression system, the payback is typically six months to three years, depending on climate.

Production Equipment

Energy Efficient Electric Motors

The Energy Policy Act of 1992 (EPACT) requires that general purpose electric motors from 1 to 200 horsepower manufactured in the United States meet minimum energy efficiency standards starting October 1997.

Energy efficient electric motor (EEM) replacement should be considered at least in the following scenarios:

- When purchasing new electric motors or motor driven equipment
- During major equipment overhauls
- As part of an energy management or motor retrofit program
- When a motor requires repair
- To replace undersized or overloaded motors

In general, energy efficient motors can cost as much as 15 percent more than standard efficient motors. The benefit, however, is that the energy efficient motor can pay for itself when compared to a standard efficient motor. The following equation demonstrates savings:

$$\$ = 0.746 * hp * L * C * T (100/E_s - 100/E_e) \quad \text{Eqn. 1}$$

where:

hp = motor hp

L = load (%)

C = cost (\$/kWh)

T= run hours (hrs/yr.)

E_s = Standard efficient value

E_e = Energy efficient value

The following table demonstrates the incremental cost of buying a high efficiency motor over a standard efficiency motor. When motors need to be replaced, this table gives the cost that must be recovered by the savings (this is not the cost of the entire motor, since the motor must be replaced anyway).

This is followed by an example showing savings and payback based on the decision to purchase an energy efficient motor.

Horsepower	1 Shift, 5 days per week (2080 hrs/yr.)	2 Shifts, 5 days per week (4160 hrs/yr.)	2 Shifts, 6 days per week (5000 hrs/yr.)	3 Shifts, 5 days per week (6240 hrs/yr.)	3 Shifts, 7 days per week (8760 hrs/yr.)
5	27	54	65	81	114
10	49	97	117	146	205
15	65	130	156	194	273
20	80	160	192	240	337
25	98	197	237	295	415
30	126	253	304	379	532
40	147	293	353	440	618
50	159	318	383	478	671
75	200	400	481	600	843
100	265	529	636	794	1,114
125	343	686	824	1,029	1,444
150	367	735	883	1,102	1,547
200	436	872	1,048	1,308	1,836

Given: Electricity Cost=\$0.05 / kWh; 1800 RPM; 100% loaded efficiency
Values, in US dollars

EXAMPLE:

A large plastics plant operates three-shifts, five-days per week. One of the production machines requires a new 50hp motor. The choice is made to purchase a 94.5 percent efficient motor instead of a standard 89 percent efficient motor. Assuming the machine is running full time at 90 percent load and electricity costs \$0.05/kWh, equation one predicts a savings of \$686/year. The incremental cost of using this motor is \$478.

First Year Savings	\$686
Insulation Cost (installed)	\$478
PAYBACK (YEARS)	0.7 years (8.4 months)

Compressed Air

Compressed air is a necessary but expensive commodity for the plastics manufacturer. It typically ranks in the top three users of electricity within the plant. The good news is there are many opportunities to reduce the cost of producing compressed air. Many are low cost opportunities.

The specific things you want to consider are:

- Eliminating leaks from the compressed air system
- Reducing operating pressure
- Using outside air for compression
- Installing engineered nozzles

Leaks:

Leaks in a compressed air system are costly. Many times these leaks can be mitigated or eliminated altogether with a basic but rigorous leak detection/elimination program. The following table demonstrates the cost of leaks.

Equivalent Hole Diameter (inches)	Free Air Wasted at 100 psi (Million cu. ft./year)	Energy Wasted per Leak (kWh/h)
3/8	90.4	29.9
1/4	40.3	14.2
1/8	10	3.4
1/16	2.6	0.9
1/32	0.63	0.2

Leaks are most often detected in the following locations:

- Hose connections
- Shut-off valves
- Pipe connections and flanges
- Hoses
- Clamps
- Worn air cylinders

There are several ways to detect leaks. The easiest is to listen carefully to the equipment during periods of low noise. Ultrasonic equipment may be used to find smaller leaks.

When a leak is detected, it should be repaired immediately. This can be done as part of normal maintenance by plant personnel.

The following table demonstrates savings by repairing leaks in two different compressed air systems. The paybacks are almost immediate!

System	Energy Savings (MMBtu/yr.)	Utility Savings (\$/yr.)	Installed Costs (\$)	Simple Payback (yr.)
Single comp. 100 psi	230	\$3,540	\$934	0.3
Multi comp. 110 psi	118	\$2,760	\$500	0.2

Reducing System Pressure:

In many cases, compressed air system pressures are set arbitrarily high to compensate for leaks in the system and poor air distribution designs. If the pressure is in excess of 10 psi, significant savings are available. The following table demonstrates these opportunities.

System	Energy Savings (MMBtu/year)	Utility Savings (\$/year)	Installed Cost (\$)	Simple Payback (year)
115 psi to 100	187	\$2,730	\$864	0.3
115 psi to 100	77	\$1,180	\$270	0.2

Using Outside Air:

Air compressors operate more efficiently when compressing cool rather than warm air. Since there is a considerable amount of waste heat generated by plastics plants, the outside air will almost always be cooler than inside air. By allowing the use of outside air for compression, the following savings are available. Savings are dependent on size of the compressor and load factor.

System	Energy Savings (MMBtu/year)	Utility Savings (\$/year)	Installed Cost (\$)	Simple Payback (year)
Outside Air Use	82	\$1,246	\$593	0.5
Outside Air Use	34	\$490	\$780	1.6

Engineering Nozzles:

In various molding processes, compressed air is used to accelerate product cooling, clean molds and to separate stacked molded pieces. Often the air outlet is nothing more than a pipe with holes drilled into it. This is equivalent to a leak or leaks in your system.

The solution is to buy engineered nozzles, which are designed to distribute a quantity of air in a variety of patterns. These nozzles will use less air but accomplish the same task. The following example demonstrates the expected savings from implementing this energy conservation measure.

EXAMPLE:

An injection molding company was using a manifold of 5/16 inch tubing connected to the compressed air system to cool parts as they came off the presses. Engineered nozzles were recommended and installed to reduce the volume of air required to cool the parts.

First Year Savings	\$2,150
Insulation Cost (installed)	\$125
PAYBACK (YEARS)	Immediate

Low grade waste heat is also available for capture if desired. This heat can be used to provide supplemental space heat in the winter.

Maintenance Issues

One of the objectives of an energy management program is to reduce the amount of energy needed to produce one unit of output. Probably the highest initial rate of return will occur through the establishment of a good maintenance management program. If your company employs poor maintenance practices of mechanical and/or electrical systems, profit dollars are being lost.

There are five basic levels, or degrees, of maintenance:

- **Reactive Maintenance (RM):** The practice of operating equipment to failure without performing any basic tasks. This type of maintenance tends to be expensive, as you have to carry spares or pay emergency charges when critical equipment fails. In addition, the equipment itself tends to be unreliable and, if it is production equipment, may produce substandard parts.
- **Preventive Maintenance (PM):** Is the practice of performing the basic necessary tasks, such as cleaning and greasing, outlined by the manufacturer of the equipment, or through experience. In order to be effective, planning and scheduling of these tasks, along with

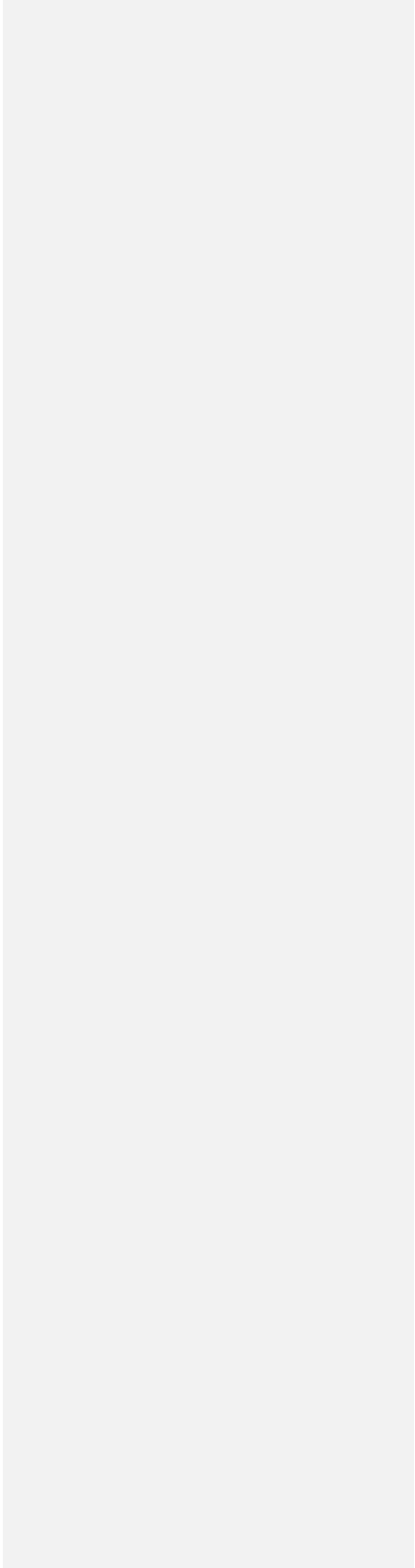
“work orders” or “work instructions” with tasks being performed by qualified personnel is recommended. This practice is designed to help the equipment operate through its design life, but does still end up with unplanned downtime of equipment.

- Predictive Maintenance (PdM): Is the practice of performing regular, measurable, and repeatable testing on equipment in order to help determine when equipment will fail to operate as designed. Types of PdM include: vibration analysis; infrared analysis; and circuit testing. This tool, used in conjunction with a good PM program can help schedule downtime so that corrective maintenance can be performed, as opposed to shutdowns during production runs.
- Corrective Maintenance: Is the practice of repairing equipment that has failed to operate as designed, not including replacing basic parts as in a PM program. Whether the maintenance is being performed in-house or by an outside contractor, specifications and work instructions should be developed to ensure that the equipment is repaired within acceptable reliability and costs.
- Proactive Maintenance (PaM): Is the practice of regularly reviewing maintenance and equipment historical records in order to improve the life cycle of the equipment and system. While the other four degrees of maintenance are designed to work around expected equipment failure, this method is designed to reduce failure frequency.

In order for PM, PdM, and PaM programs to be successful, they must be scheduled on a routine basis. With modern Computerized Maintenance and Management Systems (CMMS) this can be performed along with tracking of spare equipment and maintenance consumables. However, there are a great many facilities that do not have the ability, financial or otherwise, to install and maintain a CMMS. In this case, a manual system may be installed fairly inexpensively.

A paper maintenance system may consist of a simple desk calendar and simple work instructions for performing the tasks. Determine the spacing of performance (weekly, monthly, semi-annual, etc.) and obtain a list of the equipment to be maintained for each task. Determine the material and personnel requirements and record them on the work instruction sheet and in a notebook. Also, determine the materials availability so that they may be ordered or stored prior to use for

the maintenance. Then schedule the maintenance tasks on the calendar. Keep detailed records of the performance of these tasks so that they may be reviewed periodically for PaM purposes.



Plastics Energy Assistance Grant Case Studies

The state of Illinois' Department of Commerce and Community Affairs Bureau of Energy and Recycling (DCCA) conducted a pilot project to demonstrate the effect and feasibility of energy efficiency investments within the plastics industry. This program provided matching grants of up to \$50,000 per company on a competitive basis to partially finance energy retrofits and process efficiency improvements. The following paragraphs describe the case studies that were funded during the program. These represent actual implementations where the savings was stipulated and later measured and verified.

Case Study #1

Facility:

A medium-sized Block Molder in western Illinois, which processes Styrene/Polystyrene. This company has approximately 25 employees and operates about 8 ½ hours per day, 5 days per week.

Project:

The project for this particular facility was to install an energy efficient, three pass, 150 HP gas fired boiler to replace the old 200 HP inefficient boiler, which was showing signs of boiler tube leakage. In the year prior to installation of the new boiler, the old boiler was down for 15 of the 245 production days. Eliminating this down time increased production by 6.1 percent. The old boiler fired at an average combustion efficiency of 65 percent. The new boiler fires at an average combustion efficiency of 82 percent.

Cost:

Cost and installation for the boiler and all the auxiliary equipment associated with the operation of the boiler was \$76,551.

Savings:

The savings associated with the energy efficiency improvement were calculated at \$8,122 per year. The benefit to the company due to increasing production time was calculated at \$9,000 per year resulting in a total savings of \$17,122 per year. The resulting economic payback for this investment was 4.4 years. This case study resulted in an excellent investment for the company and increased plant up-time.

*Case Study #2***Facility:**

A small thermoforming company in northern Illinois, which processes PVC, Styrene/Polystyrene, ABS, PETG, and Polyethylene. This company has fewer than 10 employees and operates approximately 9½ hours per day, 5 days per week.

Project:

The project for this facility consisted of two parts. The first was to replace the electric cal-rod ovens in the primary vacuum forming machine with gas catalytic ovens. The second was to replace two old inefficient vacuum pumps and motors with a single, lower horsepower unit that was more efficient.

Thermoforming is a technique used for processing plastic compounds into useful products. Thermoformers heat a plastic sheet with infrared electric heaters to just below the melting range, then apply a force to draw it down into open, chilled molds. A catalytic gas heating system was installed in the same space as the infrared electric heaters without interrupting operation through weekend installation. An immediate increase in productivity was accredited to the plastic sheet's ability to absorb energy from the gas heater at lower temperatures which reduced the time required to cool the part after it had been molded. The energy dollar savings associated with this particular conversion from using natural gas to electricity was estimated to be \$11,377 per year.

Two-11 ½ hp vacuum pump motors used 11.09 kW x \$0.184/kWh and ran 2000 hours per year, using \$4,080 of electricity per year. The single, 7 ½ hp replacement pump uses 7.12 kW @ \$0.184/kWh for 2000 hours per year for a cost of \$2,620 per year. This yielded an electric savings of \$1,460 per year.

Comment [MC1]: How was this number derived (or was it measured)

Cost:

Cost and installation for the oven & controller was \$28,190. Cost & installation for the vacuum pump & motor was \$5,554. Total project cost was \$33,744.

Savings:

Calculated annual savings submitted in the report was \$12,837. Subsequent utility bill analysis estimates the annual savings to be \$13,206, resulting in a 2.56 year payback. This case study resulted in an excellent investment for the company.

Case Study #3

Facility:

A large-sized injection molder in the Chicago area that processes Polypropylene, Styrene/Polystyrene, Thermoplastics, Nylon and Polyethylene. This company has approximately 70 employees and operates 24 hours per day, 5 days per week.

Project:

The project at this facility consisted of two parts. The first part included the installation of power conditioning equipment and the second part included the installation of thermal insulation blankets.

The power conditioning devices are a combination of capacitors, inductors, resistors and Metallic Oxide Varistors (MOVs). The units are designed to improve power factor; reduce line losses, phase imbalances, total harmonic content, surges, spikes, transients and lightning problems; reduce current drawn by the load being served; and improve equipment uptime. Testing

performed by Ensol Products, Inc. showed an energy reduction averaging 10.3 percent per installed 240 Volt unit. Measuring other effects was not done because it was either impractical or too time consuming.

The thermal insulation blankets were installed on the plastic injection mold machine barrel heaters. The purpose of these blankets was to maintain consistent barrel temperatures for longer periods, thus resulting in reduced energy demands.

Cost:

Installed cost for the power conditioning units was \$37,800. The installed cost of the thermal insulating blankets was \$8,903.

Savings:

In virtually all cases, the power conditioning units did improve power factor; however, many power factor correction devices are available at much less cost. The predicted savings of 10.3 percent were high. Actual savings of 2 to 4 percent can be expected with an approximate six year payback on this type of device. Paybacks might be lower if greater power factor correction is achievable or the plant was being penalized for poor power factors.

The barrel temperatures were measured before and after installation demonstrated a change in exterior temperature averaging 150 °F. This resulting savings is approximately 870 Btu/hour. This equates to a dollar savings of \$1,342 per year yielding a simple payback of 6.6 years.

Case Study #4

Facility:

An above average-sized injection molder, which processes Polypropylene, PVC, Styrene/Polystyrene, Nylon, Polyethylene and other plastics. This company has about 86 employees and operates 24 hours per day, 6-7 days per week depending on holidays and job requests.

Project:

A hydraulic molding press utilizes electric pumps to develop the hydraulic pressure necessary to operate the equipment. The electric pumps are required to run constantly to maintain the hydraulic response time necessary to operate the equipment.

The project at this facility consists of replacing a hydraulic molding press with an electric molding press where the mechanical motion, and pressures required are developed directly by electrical and mechanical means, eliminating hydraulic systems.

Cost:

Cost and installation for the electric press was \$121,244. A similarly equipped 120 ton hydraulic press has been quoted at \$101,750 versus the price of the electric press at \$113,275. Assuming the cost of installation is equal, the purchase price differential between the hydraulic press and the electric press is \$11,525.

Savings:

Annual savings was estimated to be approximately \$4,540 yielding a payback of over 26 years if based upon replacement cost. However, if incremental cost was used and the evaluation was based on the difference in cost of the electric machine vs. the hydraulic machine, then the simple payback would be 2.5 years.

*Case Study #5***Facility:**

A large plastic extrusion facility, converting high-heat crystal polystyrene (pellets) into polystyrene sheets for the packing industry. The company employs over 100 employees in northern Illinois and operates 24 hours per day, 365 days per year.

Project:

The process involved using a 250-ton chiller system to control temperatures for the extrusion line. The chiller introduces cold water into the extrusion equipment, takes heat out of the process, and returns warm water back to the chiller for re-chilling in a closed loop method.

The project used the warm water returned from the process to heat some of the make up air, which is required to maintain proper building pressure. This reduced the electrical load on the chiller system and the amount of natural gas used by the make up air system.

Cost:

Complete installation of the heat recovery system \$93,300.

Savings:

Measured savings were \$11,915 per year yielding a simple payback of 7.8 years.

*Case Study #6***Facility:**

A very large company whose principal product or service is injection and Reinforced Reaction Injection Molded (RRIM) painted automotive fascias and bumpers. Located in southern Illinois, it employs over 600 people and operates 24 hours per day, 5 days per week.

Project:

This particular company is a tier one supplier of injection molded and RRIM fascias, body panels and bumper systems to the automotive industry. Parts are given a class A painted automotive finish prior to shipment to the assembly plants.

Volatile Organic Compounds (VOCs) are produced during the painting operation and a Regenerative Thermal Oxidizer (RTO) was designed as a pollution control device for the paint booth exhaust air. The RTO was designed to raise the VOC-laden process exhaust to its incineration temperature. The VOCs are thereby converted to carbon dioxide and water vapor that can be released to the atmosphere.

The project calls for converting the existing RTO abatement system to a Regenerative Catalytic Oxidizer (RCO). The conversion is accomplished by adding a 9-inch layer of proprietary manganese oxide catalyst impregnated rings to each of the existing ceramic heat recovery beds of the abatement system. A thin layer of ceramic saddles is then placed on top of the catalyst impregnated rings to protect the catalyst from the radiant heat of the burners. The catalyst allows the destruction of VOCs at lower temperatures by lowering the activation energy required for the oxidation to begin. The RTO system was operating at a combustion chamber temperature of 1,450 °F. After the conversion to the RCO technology the combustion chamber temperature was approximately 850 °F.

Cost:

The total cost of the project was \$536,000.

Savings:

The savings calculations were based on achieving a combustion chamber temperature of 850 °F. Therefore the estimated savings for this project is \$267,500 per year yielding a two year simple payback.

Case Study #7

Facility:

A large injection molder and extruding company in northern Illinois that processes Polypropylene, Styrene/Polystyrene, Nylon, Polyethylene, and other plastic types. The company employees over 650 employees and operates 24 hours per day, 7 days per week.

Project:

Installed an Electric Power Energy Management System to monitor all electric energy used at production and distribution facilities. The goal was to reduce operation cost by ultimately controlling kilowatt (kW) demand charges without reducing the production required kilowatt-hours (kWh). The ECM will provide the electrical data necessary to both understand and control noncontinuous or intermittent kW loads that occur indiscriminately throughout a typical billing cycle. It is intended to either reschedule or lock out those electrical loads whenever possible.

Cost:

Total cost of project and installation was \$147,272.

Savings:

Savings were calculated and based on the ability to adjust from month to month projects and/or activities. Projected savings are \$94,425 per year and are currently on track. If accomplished as projected, this would yield a simple payback of 1.6 years.

*Case Study #8***Facility:**

A large thermoformer and extruder in northern Illinois, which processes Styrene/Polystyrene producing disposable food containers. This company employees approximately 800 employees and operates 24 hours per day, 365 days per year.

Project:

The project was to automate the controls and improve energy efficiency of three existing 75-ton capacity water chillers. The proposed chiller upgrades were designed to improve the old system in three ways:

The first part was to install automatic control valves for the water-to-water heat exchanger that opens whenever the outside temperature falls below 55 °F. The valves are controlled by a remote monitor and control panel and check all the water temperatures to maximize the use of 'free' tower water and minimize the running time of the electric powered chiller compressors.

The second part was to install liquid pressure amplifiers on the three large 75-ton chillers. This enabled the system efficiency to be increased by 6 to 30 percent, depending on the outside temperature.

The third part was the installation of a remote monitor and control panel, which is used to monitor the temperature differentials of the water-to-water heat exchanger and the three electric chillers. This will quickly show when the water flow is unbalanced, when a compressor needs repair, or when a heat exchanger needs cleaning.

Cost:

The total installed cost of these chiller improvements was \$49,625.

Savings:

Projected energy savings were \$36,670 per year, yielding a simple payback of less than 16 months. Preliminary measurements indicate that the savings will far exceed the estimated levels.

Case Study #9

Facility:

A large extruder and thermoformer located in the Chicago area, which processes Styrene/Polystyrene. This company employees approximately 240 people and operates 24 hours per day, 365 days per year.

Project:

The project at this facility consisted of three parts. The first was to install an economizer to recover lost boiler stack gas temperatures. The second was to install inlet guide vanes on a 1500 horsepower air compressor and the third was to purchase measuring equipment to monitor progress.

The installation of an economizer on the boiler stack allowed the company to take heat from the stack gases and preheat the boiler feedwater. By raising the feedwater temperature in this manner, the boiler requires less fuel to generate steam. The economizer was designed to take the 450 °F stack temperature and increase the feedwater temperature from 180 °F to about 230 °F.

Inlet guide vanes are used on the inlet of the centrifugal compressors in lieu of the inlet throttle valve. The effect of utilizing inlet guide vanes is to produce a flow angle to swirl the air entering the impeller in the same direction as the rotation of the impeller. This type of control results in an increase in efficiency at part load versus a typical butterfly type throttle valve.

Cost:

Total cost of project was \$49,703.

Savings:

Estimated annual savings are \$54,739, of which \$20,336 per year came from the economizer, and \$34,403 per year came from the inlet guide vanes. This investment yielded a simple payback of 11 months.

Economic Considerations

When a plant manager must allocate budget, primary decisions are often based on the needs of the plant. Other decisions, such as implementation of energy conservation opportunities are based on economic viability. Typical economic analysis tools are:

- Simple Payback Method
- Rate of Return
- Life Cycle Cost Analysis

The Simple Payback Method is the simplest of the three. Basically, the payback period of an investment must be below a predetermined number in order to be feasible. The following equation demonstrates the Simple Payback Method.

$$\text{Payback Period} = \frac{\text{initial investment}}{\text{pretax or after tax savings}}$$

Payback periods of less than two years are generally funded. Longer payback periods may be justified on the basis that

- Fuel pricing will increase at a higher rate than the general inflation rate, and/or
- The 'risk analysis' for not implementing energy utilization measures may mean loss of production and loss of a competitive edge in the market.

The Rate of Return method is slightly more sophisticated in that it takes into account the time value of money. By investing today in energy conservation, yearly operating dollars over the life of the investment will be saved. A dollar in hand today is more valuable than one to be received at some time in the future. For this reason, the time value must be placed on all cash flows into and out of the company.

Investment decisions also take into account alternate investment opportunities. In order to compute the rate of return on an investment, it is necessary to find the interest rate that equates payment outgoing and incoming for today and tomorrow. This is referred to as discounted cash flow and can be calculated with any spreadsheet-type software. The following example illustrates the use of rate of return.

EXAMPLE:

A plastics plant is considering investing in one of two energy conservation measures. The first energy measure requires an investment of \$55,000 and will return \$23,500 per year. The second measure requires an investment of \$42,000 and will return \$14,750 per year. The following table demonstrates the three and five year rate of return for the two measures. Based on the results, the measure should be funded.

Year	Today	1	2	3	4	5	3-YR ROR	5-YR ROR
Investment/ Return Measure #1	-\$55,000	\$23,000	\$23,000	\$23,000	\$23,000	\$23,000	14%	32%
Investment/ Return Measure #2	-\$42,000	\$14,750	\$14,750	\$14,750	\$14,750	\$14,750	3%	22%

A life cycle analysis is an analysis of the total cost of a system over its anticipated useful life. These analyses are very detailed and include factors such as interest rates, useful life, inflation rates, changing maintenance costs, depreciation of equipment, etc.

The Alliance to Save Energy, Washington, DC has an investment analysis software package, ENVEST. This program enables users to

- Generate spreadsheets and graphs showing the yearly cash flows from any energy-related investment

- Compute payback, rate of return and other important investment measures
- Experiment with differing energy price projections
- Perform sensitivity analyses on key assumptions
- Compare alternative financing options, including loans, leases and shared savings
- Store data on over 100 energy efficiency investments.

Impacts of Deregulation of the Electric Utility

How well we understand how our plastics plant uses electricity will determine in some respect how competitive our companies will be in the future. Currently the electrical utility industry is being restructured. In some states (Illinois, California, Pennsylvania) open electrical access is currently available or will be available in the near future.

Whether you will have open access to electrical purchasing today or tomorrow is immaterial. Preparation is the key to controlling utility costs and maintaining a competitive edge. All the demand-side issues discussed in this handbook will help identify your electric baseload. Once determined, this baseload can be optimized to insure your plant will be able to negotiate a very favorable rate for electricity purchased.

Things you can do today to prepare for deregulation:

- Get your 30-minute electric demand data from your electricity provider for the last 12-24 months. This will help determine your demand profile for your plant. There may be a nominal fee for this data; however, it is invaluable to you.
- Read and understand your existing electric tariffs and pertinent riders. In the future you will have to compare contracts from several different electricity providers to determine which one is best for your plant.
- Implement energy conservation opportunities previously described. This will help reduce your peak demand. Also, consider transferring some demand to an 'off-peak' shift.
- Investigate the purchase of on-site generation equipment. This equipment can be used to shed peak load and may be a good investment for your plant.
- Hire an independent energy consultant who can find opportunities for energy savings you may miss.
- Develop a Request for Proposal (RFP) for electricity. This is the only way you can find out what competitive prices the market has to offer.

Remember, today your electricity prices are set by time of day. Tomorrow your prices can vary and this variability can be disastrous for the ill prepared. The table on the following page demonstrates retail prices in the ComEd service territory published from the NYMEX Cinergy futures contract prices (June 1999) adjusted for typical load factors, mitigation factor, CTC and delivery tariffs.

Retail Electric Pricing (Sample)

Month	\$/kWh
January	\$0.0496
February	\$0.0458
March	\$0.0428
April	\$0.0431
May	\$0.0460
June	\$0.0765
July	\$0.1358
August	\$0.1204
September	\$0.0600
October	\$0.0471
November	\$0.0509
December	\$0.0475

Appendix A

ComEd Electric Rates: 6, 6T, 6L