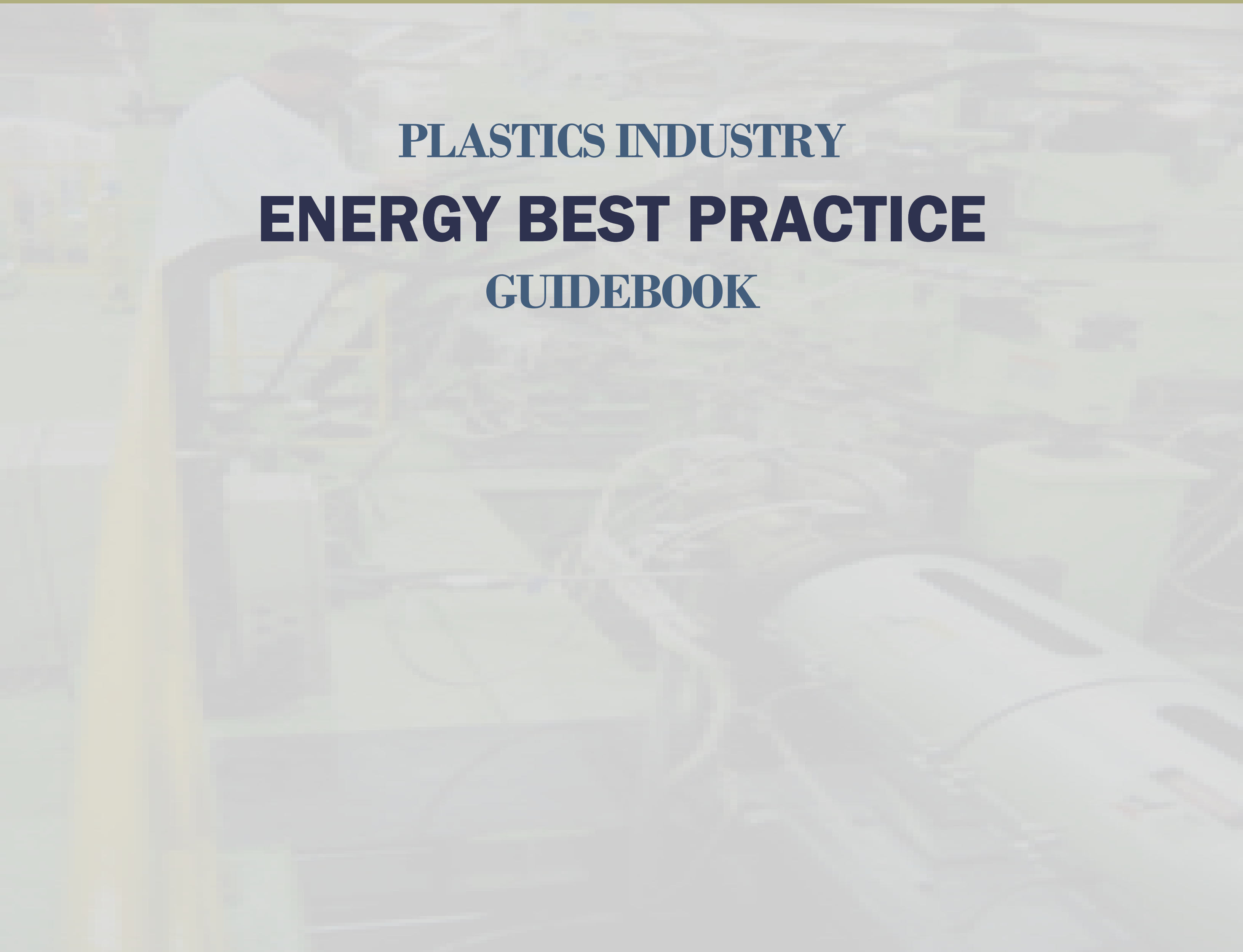
PLASTICS INDUSTRY
ENERGY BEST PRACTICE
GUIDEBOOK



focus on energy
The power is within you.

Plastics
Energy Best Practice Guidebook

Provided By:

focus on energy℠

The power is within you.

Funding for this guidebook was provided by Focus on Energy.
Focus on Energy, a statewide service, works with eligible Wisconsin residents and businesses to install cost-effective energy efficiency and renewable energy projects. We provide technical expertise, training and financial incentives to help implement innovative energy management projects. We place emphasis on helping implement projects that otherwise would not get completed, or to complete projects sooner than scheduled. Our efforts help Wisconsin residents and businesses manage rising energy costs, protect our environment and control the state's growing demand for electricity and natural gas.

With:

Science Applications International Corporation
Center for Plastic Processing Technology, UW-Platteville
Envise, LLC
CleanTech Partners, Inc.
Tangram Technology Ltd.

July 2006

Special thanks to the American Chemistry Council who provided printing and distribution through a grant by the U.S. Department of Energy, administered by CleanTech Partners, Inc.

TABLE OF CONTENTS

FORWARD

Are You A World Class Energy User?

World class energy users have:

1. Received firm commitments from management for plant-wide improvements in energy efficiency and demand reduction
2. Aligned their energy using equipment decisions with their corporate goals
3. Baselined energy consumption in their plant
4. Benchmarked best practice opportunities
5. Defined a quantifiable, affordable energy reduction goal
6. Established a multi-year plan to meet their energy reduction goals
7. Identified the necessary internal and external resources to meet these goals and to provide feedback to continuously improve plan

If your plant lacks any of these essential ingredients, this Plastics Energy Best Practice Guidebook will help you get there.

What Others Say about the Guidebook

"We have found the information fascinating and helpful. We are at present giving a challenge to our Manufacturing Management Team to come up with an energy conservation program that will be enforceable throughout the company."

Larry Floyd, Plastic Molded Concepts, Inc.

"… well-written and chuck full of good ideas! The considerable emphasis on Benchmarking and Best Practices is an excellent way to present and organize the material. I have sent [it] to our operations to get started on the process of energy management ASAP."

Lance Hampel, Hampel Corporation

"… a valuable source of information regarding Environmental Management systems that practically any plastics industry can implement… especially with the introduction of ISO 14001 and a company's commitments to become certified in this EMS. I think this book gives them the initial information required to begin that system."

Lisa Esser, Miniature Precision Components

"… an excellent reference material for someone starting an energy management program or anyone serious about conserving energy."

Greg Knudson, Northern Engraving

"… a good general resource that gets one pointed in the right direction for further research into the reduction of energy usage in a production environment."

Terry Stephens, Midland Plastics, Inc.

"*This is excellent!*"

D'Lane Wisner, Lead Staff to American Plastics Council Buildings and Construction Team

Development of the Guidebook

Funding for this best practice guidebook was provided by Focus on Energy, Wisconsin's energy efficiency and renewable energy program. The following Focus on Energy Plastics Cluster team members contributed to the development of this guidebook:

- **Craig Schepp,** Plastics Cluster Leader**,** Focus on Energy, has over 25 years of experience in the energy efficiency industry working with utility and government programs.
- **Dr. Majid Tabrizi,** Professor and Director of Center for Plastics Processing Technology at UW-Platteville. He has been an academia consultant and lecturer for the plastic industry for the last 20 years and has received a national award for his contribution.
- **Tom Tucker, P.E.,** is a Senior Consultant with EnVise LLC, a Madison, Wisconsin based energy consulting firm that specializes in supply and demand side energy management. He has performed detailed energy assessments for more than 170 facilities and worked with clients to develop energy management systems.
- **John Nicol, P.E.,** Industrial Program Manager for Focus on Energy's Business Program – more than 20 years of experience in industrial energy efficiency.
- **Brent English,** Senior Technology Analyst for CleanTech Partners, Inc. has been involved in a variety of plastics research and business opportunities for 20 years. Brent has hands-on experience in compounding, injection molding and profile extrusion.
- **Dr. Robin Kent,** Managing Director and Founder of Tangram Technology Ltd., has been a consultant to the plastics industry in the United Kingdom (U.K.) and continental Europe for over 30 years. He has conducted research and lectured on energy efficiency and waste reduction in the plastics industry throughout Europe. Currently he is Chairman of the Plastics Consultancy Network International.

Special Thanks to the Following Reviewers

We wish to extend our gratitude to the volunteer reviewers of this guidebook who represent the plastics industry. Their comments on its usefulness and value to the industry have been extremely valuable and will guide future improvements to it.

Genise Smith-Watkins
Midwest Regional Director
American Chemistry Council

Bruce Williams
Corporate Energy Manager
Bemis Corporation

Lance Hampel
CEO
Hampel Corporation

Terry Stephens
SBU Team Leader
Midland Plastics, Inc

Lisa Esser
Manufacturing Engineer
Miniature Precision Component

Tom Hartmann
Manager of Mfg Engineering
MRPC (also SPE Ex-President)

Larry Floyd
President
Plastics Mold Concepts

Greg Knudson
Plant Engineer
Northern Engraving

Bob Whitish
Plant Manager
Plastic Ingenuity

Mike Thomas
SPE Board
SPE Milwaukee-Board

EXECUTIVE SUMMARY

According to Forward Wisconsin, Inc., Wisconsin is home to over 750 plastics and plastic-related businesses and is the fourth largest industry in the state. Plastics is a diverse industrial group, including blow molders, injection molders, thermoformers, film and sheet extruders, and pipe and profile extruders. These processes require large amounts of reliable power and heat. Therefore, volatile and escalating energy costs pose a significant challenge to this industry. Plastics manufacturers must find the most effective solutions to minimize the energy cost per unit of product to keep prices down and remain competitive.

Energy efficiency in manufacturing is using the smallest amount of energy per unit of output. Savings are achieved by:

- Cutting energy usage for **basic plant processes** such as lighting and compressed air (e.g., installing more energy efficient fixtures, stopping leaks, turning off unnecessary equipment)
- Trimming energy use for **production processes** such as molding, extrusion, process cooling, and mold design.

This **Plastics Energy Best Practice Guidebook** provides resources and methods to reduce energy use and energy related costs in plastics manufacturing facilities. Using this guidebook, facility managers and technical personnel can identify opportunities that will significantly reduce energy use in their facilities.

This guidebook emphasizes not only the energy savings advantages, but the additional benefits, such as improved production, reduced waste, and lower materials and water usage that result from improving plastics-specific manufacturing processes. In this guidebook you will find:

- A discussion of **energy use in the plastics industry**
- Ways to **compare your facility's performance** with other plastics processors
- Guidelines for energy **management best practices** that will help you get started or enhance your own energy management plan
- Summaries for over **23 technical best practices** for plastics-specific production processes that have been reviewed by plastics industry leaders
- Additional tools, references and resources, including a checklist of measures you should consider

This guidebook format provides a "living" document that can be updated continually with new best practices and case studies provided by the Focus on Energy program.

Focus on Energy also provides technical assistance and financial incentives for qualifying equipment and services to support the implementation of your energy efficiency measures.
Call **800-762-7077**
to find out how Focus on Energy can help you reach your energy cost reduction goals.

INTRODUCTION

Plastic is one of several fundamental industrial materials, including metal, wood, glass, brick, stone and ceramic. Although plastic is relatively new, the volumetric production of plastics passed the production of metal and ceramic combined, in 1983. Plastic has been the #1 industrial material used in the last three decades. Today, the plastics industry is ranked as the fourth largest industry in the nation.

> *"With annual shipments of more than $300 billion and employment of more than 1.5 million workers in 23,000 facilities nationwide, the plastics industry is a major contributor to the U.S. economy."*
>
> *Society of the Plastics Industry (SPI) energy policy, October, 2001*

The United States plastics industry manufactures over 52 billion pounds of plastic annually. The production of plastic in the United States rose from 150 pounds per capita in 1999 to 174 pounds per capita in 2005. Western Europe follows in the number two position with 106 pounds per capita. Total world consumption of plastic grew from 30 pounds per capita in 1999 to an estimated 40 pounds in 2005.

The plastics industry utilizes over one hundred techniques and process variations to manufacture a vast array of different plastic products. There are four common plastics production functions: molding, calendaring, extrusion and coating, accounting for over 90% of plastics volume. The majority of plastics production occurs through injection molding, thermoforming, extrusion and blow forming.

Wisconsin's plastics industry has the distinction of being:

- Ranked 12th for the US in plastics shipments at an estimated $11 billion of shipments annually
- Ranked 10th for the US in employment, with 46,000 employees – about three times the number of workers employed by Wisconsin's dairy industry
- Ranked 9th for the US in number of plastics processing machines installed
- Home to over 750 plastics and plastic-related businesses, dispersed in 57 of its 72 counties.[1]

Wisconsin is an employment powerhouse for the plastics industry. On average, plastics businesses in Wisconsin have 71 employees; the largest plastics businesses employ over 1600 employees. In the most recent census, Wisconsin's employment in the plastic and rubber sector grew by 27%, outpacing general manufacturing employment growth by more than twice and growing almost four times the rate of the national economy. The industry is concentrated in the southeastern part of the state with 56 plants in Waukesha and 55 in Milwaukee.

While plastics processing has relatively low energy intensity compared with metal, glass and brick processing, its shear size renders the plastics industry a prominent target to improve energy efficiency.

[1] ForwardWisconsin.com

ENERGY USE IN THE PLASTICS INDUSTRY

Many businesses are interested to know how they compare with other businesses in the same industry. The easiest way to do this is to compare one's own performance with that of the industry average or with the performance standard set by industry leaders. Common performance measures are indices of production, such as kilowatt-hours per pound of polymer consumed in processing. The performance level set by industry leaders is often viewed as a benchmark standard.

The difference between the benchmark standard and the current level of performance of a given business represents the "gap", which can be bridged through the adoption of best practices. The volatile and upward trend of energy costs in today's competitive, global business environment provides strong motivation for a company to shrink that gap.

Energy benchmarking can be viewed as a five step process:

1. Determine the performance levels of top performing facilities
2. Determine the same performance levels for a business's own facility
3. Assess the gap between a business's own performance and that of top performers
4. Identify the technologies, procedures and practices that the top performers do that could also be done by the business (best practices)
5. Adopt those identified best practices that will bring the business to top performance.

While the U.S. plastics industry currently does not have benchmark data available, recent studies in Europe provide average consumption data from facility surveys that may provide a useful comparison. These surveys and facility assessments (mostly from Spain, Germany and the U.K.) provide reasonable specific energy consumption (SEC) values for eight plastics manufacturing processes. The European Commission's Reduced Energy Consumption in Plastics Engineering (RECIPE) program conducted surveys of 165 facilities to produce the "*2005 European Benchmarking Survey of Energy Consumption and Adoption of Best Practice,*" (September 30, 2005)[2]. The results for SEC by plastics manufacturing type are shown in **Table 1**.

Table 1
Average Specific Energy Consumption by Plastics Process

Type of Plastics Processing	Specific Energy Consumption (kWh/lb of polymer)
Thermoforming	2.803
Rotational Molding	2.644
Compression Molding	1.437
Injection Molding	1.414
Profile Extrusion	0.683
Film Extrusion	0.611
Fiber Extrusion	0.386
Compounding	0.286

[2] *"Reduced Energy Consumption in Plastics Engineering - 2005 European Benchmarking Survey of Energy Consumption and Adoption of Best Practice,"* September 30, 2005. SEC units were converted from metric values to kWh per lb of polymer.

While the values in **Table 1** are not benchmarks for the most efficient facilities, a facility can readily compare its company's performance with an average European facility.

The study also distinguishes between "site" SEC and "machine" SEC. A "site" value accounts for all of the energy used by a facility, including ancillary end uses, such as lighting, compressed air and HVAC equipment. "Machine" SEC's are measured values for process equipment only, e.g., a single injection molding machine. "Machine" values are a subset of "site" values. **Table 2** shows that, for those facilities sampled, machine energy accounts for an estimated 64% and ancillary end uses account for about 36% of total energy consumption.

Table 2
Average Site SEC vs Machine SEC – Injection Molding

Consumption attributable to:	**Specific Energy Consumption (kWh/lb of polymer)**	
Site, as a whole	1.302	100%
Machine only	0.839	64%
Ancillary, e.g., lighting, HVAC	0.463	36%

To get machine SEC, the machine must be metered. Knowing these values helps the facility operator understand where opportunities for reducing energy costs exist.

Comparing Site SEC Values

Dr. Robin Kent, a prominent consultant to the plastics industry and owner of Tangram Technology Ltd., in the U.K., has developed average curves for each of three major types of plastics manufacturing: **injection molding, extrusion blow molding** and **extrusion.** See **Figures 1-3,** on pages 9 and 10. These curves represent the average site SECs, by production rate, for a sampling of plastics facilities in the U.K. Since many of the processes are similar to those used in the U.S., these curves may be useful for facilities that want to see how their performance compares with an industry average.[3] To use these curves at the "site" level, follow these steps:

1. Determine your "site" SEC (kWh per ton of material produced) and production rate (pounds of polymer consumed per hour)
2. Locate the point representing your company's performance on the chart
3. Find your company's performance with respect to the average curve on the chart. If your company is:
    a. **Above the curve**, your energy usage is higher than average and you probably have ample opportunity for improvement
    b. **On the curve**, your company's performance is average and you can probably still find additional opportunities to cut energy costs
    c. **Below the curve**, your company performs better than average. Continue to look for energy management opportunities which can further reduce your energy costs

For example, in **Figure 1**, suppose an injection molder, **Facility A**, plots SEC (kWh/lb) vs Production Rate (lb/hr/machine). At about 100 lb per hour and an SEC of 0.9, the point lies

[3] These curves have been converted to English units and are derived from data provided by Tangram Technology Ltd., of the U.K.. Focus on Energy makes no written or implied claim that the data reflect the performance of the U.S. plastics industry. The study used a large sample size for each manufacturing type, self-reported data and represents a wide spectrum of facility sizes and products. The Goodness of Fit statistic (R^2) is > 0.70. Focus on Energy is grateful to Dr. Robin Kent for providing this data.

above the curve, as shown. Facility A is probably less energy efficient than the average facility. On the other hand, **Facility B**, at close to the same production rate and an SEC of 0.6 shows better than average efficiency.

Figure 1

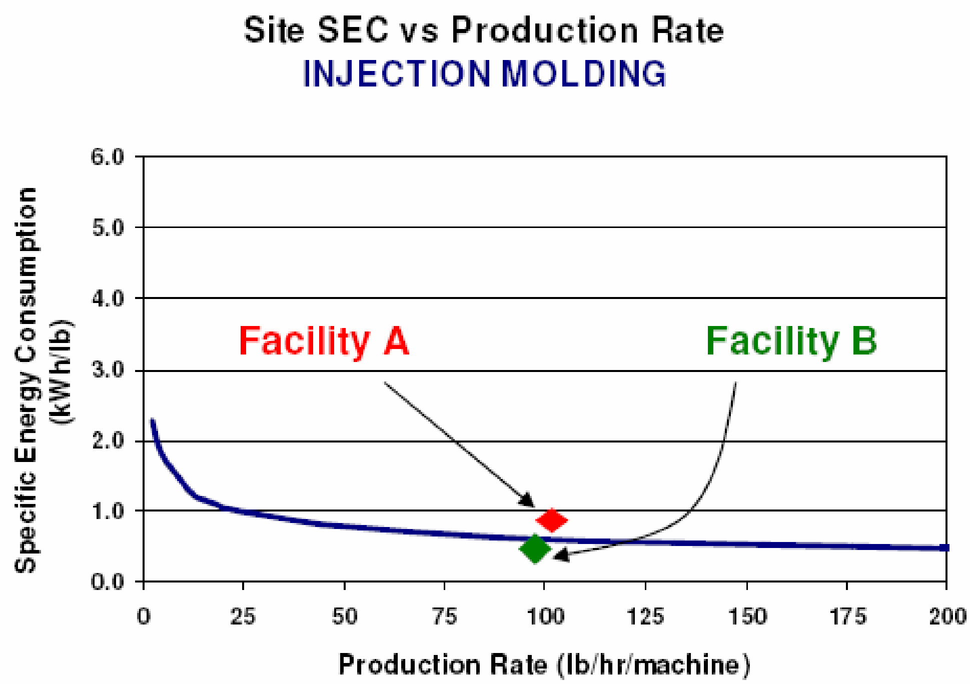


Figure 2

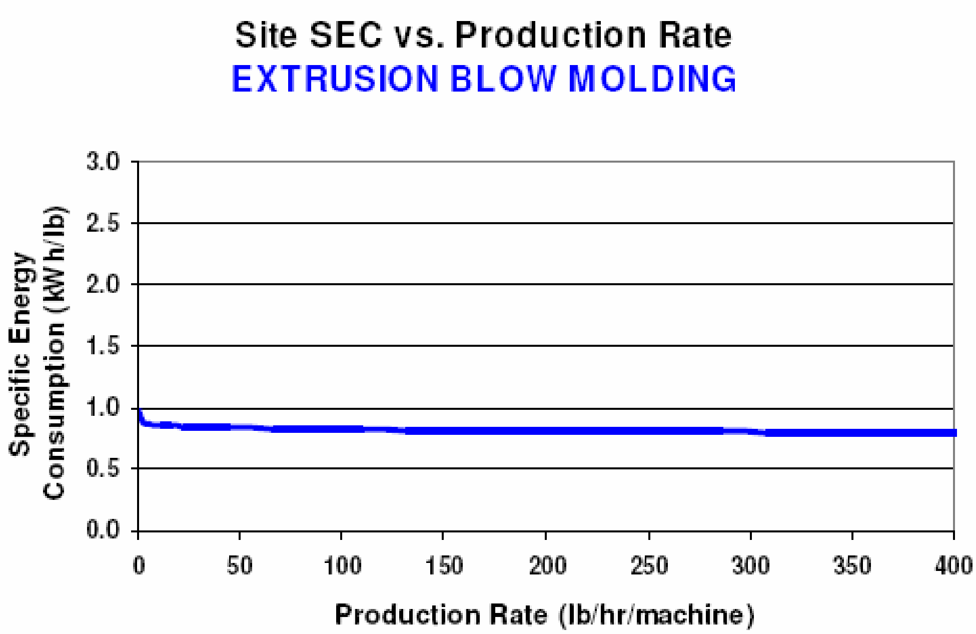
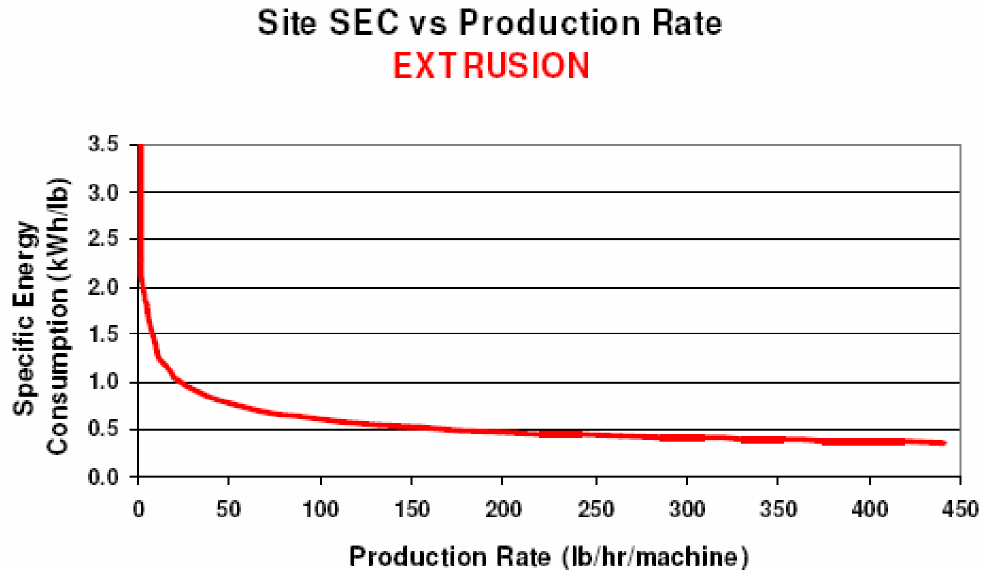
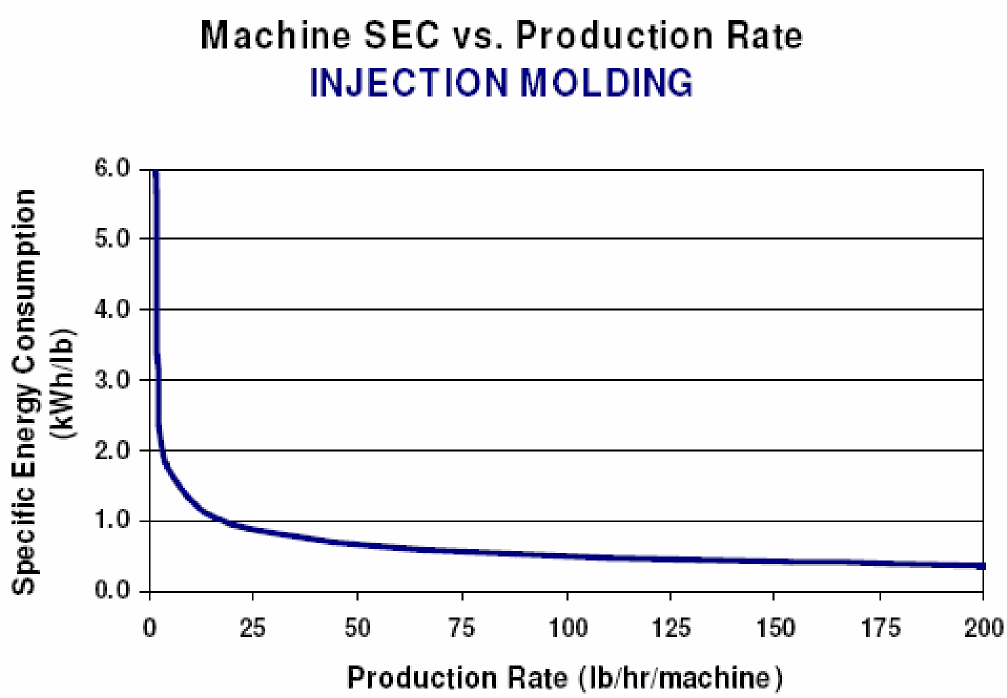


Figure 3



In addition to site average curves, Dr. Robin Kent also generated "machine" average curves for each of the three plastics manufacturing types studied (**Figures 4-6**). The SEC for a machine must be measured at the machine by power metering. If you have data on a specific machine you can apply the same steps as above to see how your machine compares with the average machine in the U.K.[4]

Figure 4



[4] Updated curves for these processes (in kWh/kg) are regularly available from Tangram Technology at www.tangram.co.uk and any processor who wishes to contribute data to the dataset can do so in confidence.

Figure 5

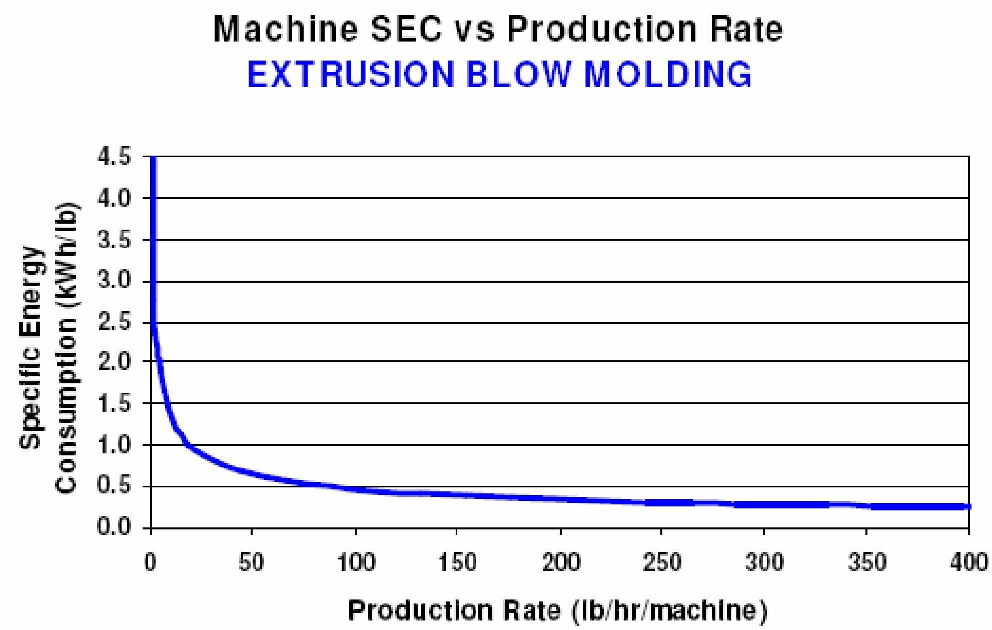
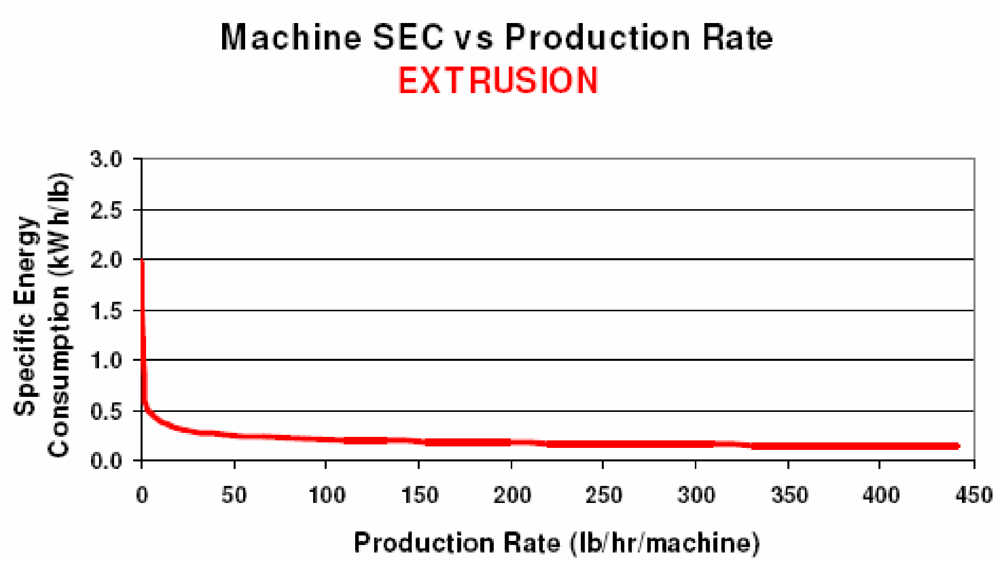


Figure 6



MANAGEMENT BEST PRACTICES

Any organization can more effectively manage its energy use and costs by adopting a continual improvement approach to energy management – an **energy management program**. An energy management program provides a systematic approach to assessing and reducing the energy uses and costs of your organization. It is a proactive approach instead of just "putting out fires" when energy costs increase.

An energy management program is not just an energy improvement project (a one-time event) but an on-going process. It can be a stand alone effort devoted exclusively to energy management or part of an existing management program such as quality assurance or environmental management. The most successful energy management programs are developed and maintained by a team of individuals from various functions such as maintenance, engineering, production, financing and management.

At first glance, creating and implementing an energy management program may seem to be an overwhelming task that pulls your attention away from daily operations. Yet taking that time up front can save you time, money and energy in both the short- and long-term. Once in place, your energy management program will deliver benefits year after year.

Energy efficiency is a good investment. Many energy efficiency projects provide a high annual return on investment – as much as 100% or more – and are low risk. Compared with other investment opportunities, these projects can be very attractive. Typically you can achieve 10% to 15% of energy cost savings in three years by implementing a systematic energy management program. The next several pages outline the first steps toward a systematic energy management program. Focus on Energy can assist you with completing any of these steps. Specifically, Focus on Energy has developed a set of tools called **Practical Energy Management© (PEM)** that can make these steps even easier.

All procedures and figures in the following section are examples of tools included in the Practical Energy Management© approach – FREE to eligible Wisconsin industries from Focus on Energy. Call 608-277-2946.

Steps to Getting Started:

Step 1: Establishing the Baseline Energy Use: Establishing an energy baseline for your facility was discussed in the previous chapter. Compile your monthly utility bills to develop an overall energy profile of your facility (see example in **Figure 7**). Put energy in the context of overall organizational operations by comparing it to more widely tracked measures such as pounds of resin processed, weight of sold product or labor costs. Then develop your facility's **Energy Profile Summary**, showing changes in consumption and in your **Key Performance Indicators (KPI)**, by year (**Figure 8**).

Then begin to track and graph your energy KPI for each month. This will set your present baseline and target for your energy **KPI** (see example in **Figure 9**). Tracking this energy KPI over time gives an indication of the effectiveness of your energy efficiency efforts. Projecting the KPI forward provides a method to set targets and goals for energy use.

Your daily, weekly and seasonal variations in power use will help you understand how you are using energy and where the biggest opportunities for savings lie. Since many facilities are billed for electricity on a time-of-use basis, the time at which you are using energy provides invaluable information on how to reduce demand charges. A demand graph also helps you find the 'base load' – the load used for heating, lighting, compressors and pumps when you have no production. Your demand profile for peak days during a month is typically available from your electric utility.

You can establish the factory base load and variable loads for energy usage and production rates with existing data. Record the factory output in pounds of resin or product processed for a number of months or weeks along with the energy usage for the same period. A plot of energy use (kWh or therms) versus production level can then be made. **Figure 10** shows the typical 'line of best-fit' for the data. The intersection of the line with the 'kWh consumed' axis is the base load for the factory, i.e. the energy use when no production is taking place.

Step 2: Estimate Energy Use for Major Systems: Determine the energy used by major equipment and energy-using systems. This can reveal your largest energy uses and the best places to target (see example in **Figure 11**). Tools within PEM© can help estimate annual energy consumption.

Step 3: Identify Best Practice Opportunities: Best practices are techniques or technologies generally recognized as being economical and more energy efficient than common or typical practices. Review best practices in comparison to your equipment and system profiles to identify opportunities for energy efficiency improvement. The next chapter highlights many of the key technical best practices for the plastic industry.

Step 4: Quantify Savings and Project Costs of Best Practice Opportunities: Once the technical best practice opportunities are identified, the next step is to estimate the cost savings for the key projects including energy and maintenance, and the installed cost of the project. Focus on Energy can provide technical assistance for quantifying energy savings for projects as needed.

Step 5: Prioritize Projects: If you did not begin with strong upper management commitment, this step is a natural place to present the technical opportunities to reduce energy costs and to align your project goals with your corporate business needs. Apply criteria such as return on investment (ROI), capital cost or ease of installation to help you prioritize among all the possible energy savings projects you have identified. Select the highest scoring projects for implementation to achieve your energy savings goals within time and budget constraints.

Step 6: Project Management: Manage each identified energy project as you would any other project within your organization by clearly defining the project parameters, assigning responsibilities for the project implementation, setting deadlines and undertaking specific tasks needed to implement the project.

Figure 7
Tracking Monthly Energy Costs and Production Units

Big Time Plastics

Electric Rate
0.046

Month	kWh/lb of Resin	Consumption (kWh)	Prod Units Lbs Resin	Billed Demand (kW)	Total Electric Power Cost
Jan	2.61	2,253,250	862,560	4,953	$103,650
Feb	2.51	2,123,070	845,040	4,953	$97,661
Mar	2.57	2,198,420	855,090	4,953	$101,127
Apr	2.49	2,056,720	826,640	4,953	$94,609
May	2.42	1,989,730	821,970	4,953	$91,528
Jun	2.49	2,106,030	844,490	4,797	$96,877
Jul	2.45	2,034,040	831,540	4,794	$93,566
Aug	2.50	2,102,320	840,200	4,728	$96,707
Sep	2.45	2,060,210	839,310	4,771	$94,770
Oct	2.41	1,983,040	821,180	4,771	$91,220
Nov	2.45	1,964,920	801,040	4,771	$90,386
Dec	2.45	1,988,640	810,940	4,771	$91,477
AVG	2.49			4,847	
Total		24,860,390	10,000,000		$1,143,578

Figure 8
Facility Energy Profile – Summary

(Does not include gas, water or other utilities that should also be tracked.)

Electricity	2005	2004	2003	% Change 2004 to 2005
Consumption (kWh)	24,860,390	26,274,784	23,647,305	-6.6%
Electrical cost ($)	$1,130,698	$1,156,090	$1,040,481	-2.2%
$ per kWh	$0.046	$0.044	$0.044	4.5%
Key Performance Indicators				
Lb of resin	10,000,000	10,028,500	8,957,500	-0.3%
KWh per lb of resin	2.49	2.62	2.64	-5.0%
Electric $ per lb of resin	$0.1145	$0.1153	$0.1162	0.7%
Business Indicators				
Operating costs	$15,000,000	$13,850,000	$12,900,000	8.3%
Electricity as % of operating costs	7.54%	8.35%	8.07%	-9.7%
Total facility costs	$33,500,000	$34,000,000	$31,500,000	-1.5%
Elec cost as % of facility cost	3.37%	3.39%	3.30%	-0.6%
Annual profits	$3,450,000	$3,750,000	$3,200,000	-8.0%
Electricity as % of profits	32.8%	30.7%	32.5%	6.8%
% increase in profits with 5% reduced energy costs	1.7%	1.4%	1.6%	

Figure 9

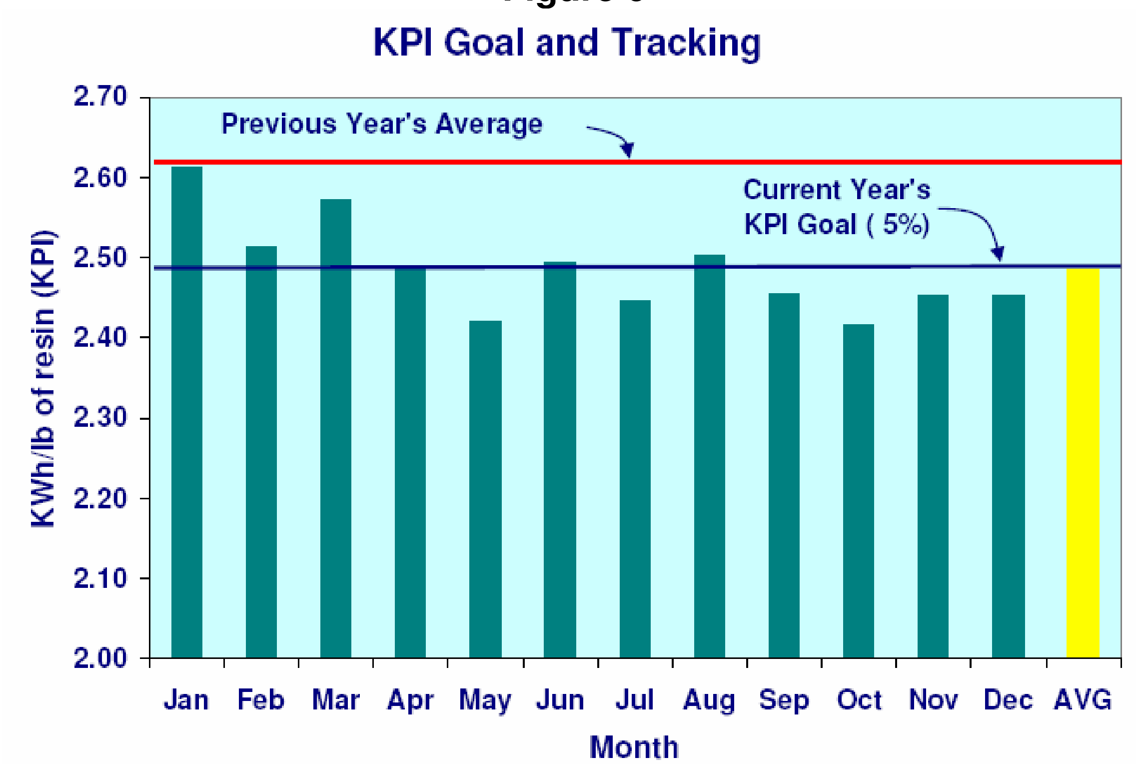
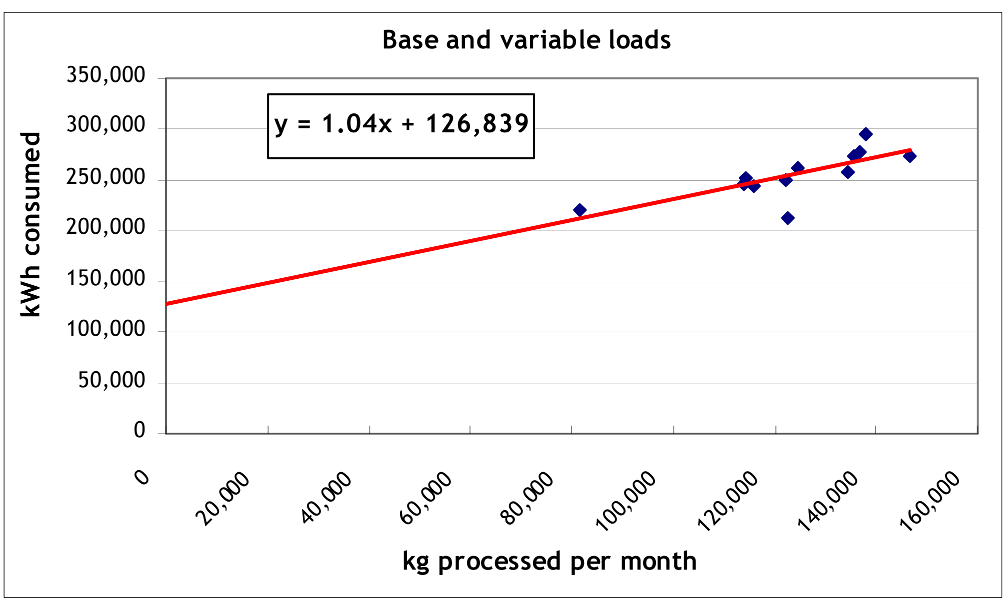


Figure 10

Typical Plot of Base Load and Variable Load

(Note: U.S. values would be in lb processed per month)



Courtesy Tangram Technology Ltd.

NOTE: This limited data set (12 months only) for **Figure 10** has been fitted with a linear line of best fit of the equation:

kWh = 1.036 x (kg. processed in month) + 126,839

The intersection of the best-fit line with the 'kWh consumed' axis indicates the 'base load' for the factory, i.e., the energy use when there is no production. For the example, the base load is 126,839 kWh. Therefore, even with no production the factory consumes about 126,839 kWh per month. On this basis the base load represents approximately 50% of the average cost of energy.

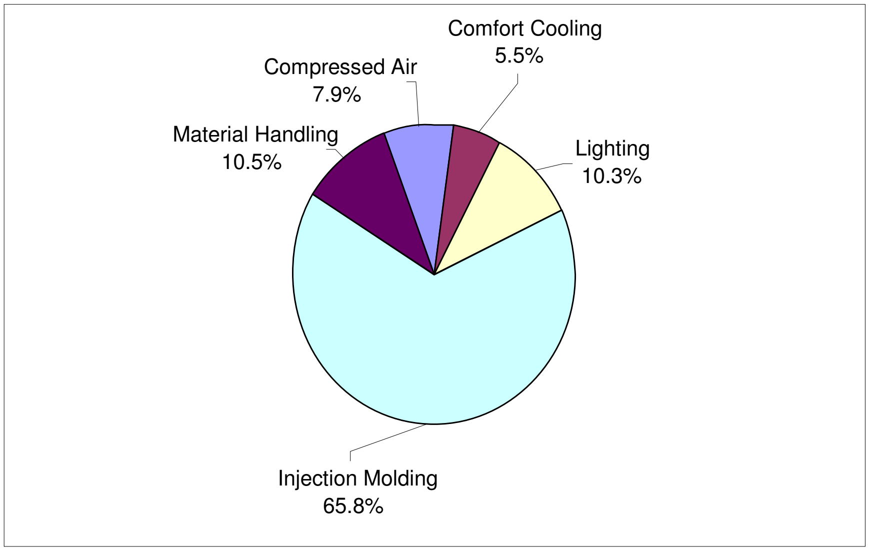
Reductions in the base load can be made without affecting production rates, quality or operations, and are usually extremely profitable to carry out.

The slope of the 'line of best-fit' is the variable part of the KPI of the actual production process and indicates the actual energy being used to produce the part. From the graph, the current process variable KPI is 1.036 kWh per kg. This means that each kg of plastic uses about 1.036 kWh to process. Reductions in the variable KPI (the slope of the graph) indicate improved process and operational efficiency.

You need to gather and process this available data to help target KPI improvements for both the base load and variable components of energy use.

Figure 11

Estimated Electric Energy Consumption



Steps for On-going Energy Management:

Step 1: Strong Commitment from Management: Critical to the success of long-term energy management is strong commitment from the management. Without this, the time spent on other steps may not significantly enhance energy efficiency.

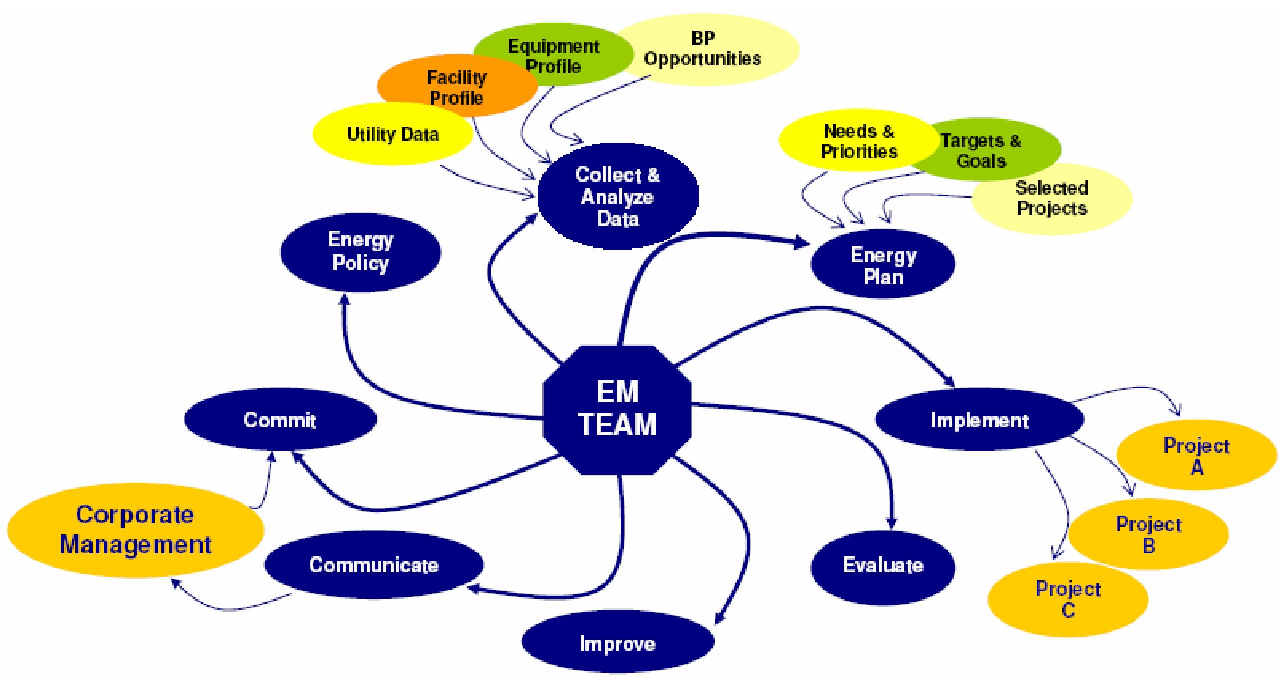
Step 2: Form an Energy Team: An energy team formed from across the company should include personnel from maintenance, engineering, production, management and financing. This team should meet periodically as needed to review progress on the energy management plan and set new direction.

Step 3: Develop a Long-term Energy Management Plan: The first task for the Energy Team will be to develop a long-term Energy Management Plan. This plan should define the goals, tasks and responsibilities for implementing and operating an energy management program within your organization. **The steps in the previous section entitled "Steps to Getting Started" should be used at this phase.** The Practical Energy Management tool can be used to help complete these steps and your plan.

Step 4: Implement Plan and Track Results Using Key Performance Indicator: With project priorities established in the long-term plan, provide project management responsibilities and monitor results of individual projects and overall KPI impact.

Step 5: Establish a System for Continual Improvement Feedback (Figure 12): Maintaining an effective energy management program requires positive and negative feedback to the plan and communicating results throughout the organization. To the extent possible, integrate the administration of the energy management program with existing management programs such as quality control, safety or environmental management.

Figure 12 – Continual Improvement Cycle



TECHNICAL BEST PRACTICES

Technical Best Practices are the specific energy efficiency measures that can be implemented in a facility's energy management plan. They are the changes that create actual energy savings. They are also the means by which a facility achieves its energy benchmark goals.

This section is divided into the four main segments of plastics manufacturing found in Wisconsin – **blow molding, injection molding, thermoforming,** and **extrusion** – so that guidebook users can quickly go to the section relevant for their facility and then into **general facility** applications, those that serve the energy needs of all types of plastics manufacturers. **Table 3** on the next page provides a quick index of current technical best practices identified for this guidebook.

Each section begins with an introductory discussion of the general best practice opportunities and offers some standard industry tips to achieve energy savings. This discussion is followed by more specific technical best practice summaries that include basic information such as energy savings, economic and productivity benefits, and market status.

While all of the best practices save energy, some also **improve production** and are duly noted in the descriptions. Improved production can materialize as increased output, improved product quality, reduced cycle time, reduced downtime, reduced material waste and reduced water use.

The major energy units used in this document are millions of Btus (MMBtu) and kilowatt hours (kWh). Unless otherwise stated, costs were assumed to be: $5.00 per MMBtu and $0.045 per kWh ($275 per hp per year). Many facilities will have actual energy costs different from these.

The plastics manufacturing industry best practices included in this document were compiled by the development team from literature reviews, personal experience and interviews with plant and vendor personnel. In most cases resources for additional information are provided. Some of the information presented, particularly in the introductions to each of the various plastic manufacturing techniques, relies on information provided by Dr. Robin Kent, owner of Tangram Technology Ltd., an energy consultant to the plastics industry. This information is derived from his facility survey work in the U.K. and continental Europe. References to these sources are included.

Table 3
Plastics Energy Best Practices

BLOW MOLDING		
1	Pulse Cooling	
2	Match Blow Former Equipment to Material	Improves Production
3	Implement Proper Die Design	Improves Production
4	Add Performance-Enhancing Plastic Compounds to Molding Materials	Improves Production

INJECTION MOLDING		
1	Replace Hydraulic Machines with All Electric	
2	Pulse Cooling	
3	Variable Frequency Drives on Injection Molder	
4	Variable Frequency Drives on Cooling Water Pumps	
5	Implement Proper Gate Design	Improves Production
6	Add Performance-Enhancing Plastic Compounds to Molding Materials	Improves Production

THERMOFORMING		
1	Upgrade Thermoformer Element (includes controls)	
2	Design New Thermoformer with Energy Efficient Element	
3	Select Radiant Heater Retrofit to Match Plastic Compound Thermal Properties	Improves Production
4	Apply Proper Part Design	Improves Production
5	Select the Sheet with Proper Physical and Chemical Characteristics	Improves Production
6	In-line Thermoforming	Improves Production
7	Infrared Scans of Inputs, Processes and Waste Streams	

EXTRUSION		
1	Post Heating of the Extrudate	
2	Implement Proper Die Design	Improves Production
3	Add Performance-Enhancing Compounds to Materials	Improves Production
4	Convert DC Drive to AC Drive	

GENERAL FACILITY		
1	Free Cooling	
2	Improve Energy Awareness Through Monitoring	

BLOW MOLDING

For blow molding, the specific energy consumption (the energy used to process a pound of polymer) varies from 'typical' values of 3.3 to 4.4 kWh/lb up to 'high' values greater than 6.6 kWh/lb. If your factory SEC is greater than 4.4 kWh/lb there are some real savings available – 5% to 10 % can be achieved through simple low-cost measures[5].

Machine

The major component of energy use is the extruder area which typically uses 40% of the total energy. As with other processes, energy efficient machines have lower, long-term operating costs than standard machines and will pay back any extra investment.

All electric machines are the most energy efficient option for blow molding because these machines remove the energy losses at the electro-hydraulic interface. Process control also improves efficiency. New improvements in process controllers make investigating upgrades worthwhile. Controlled, accurate and minimized wall thickness and parison length, also improve energy efficiency and materials usage.

Extrusion blow molding machines use only small amounts of externally applied heat, (most is generated mechanically) but heat transfer from barrel heaters can be maximized and evenly distributed by good seating on the barrel and the use of conductive metal compounds. Extrusion blow molding sometimes uses heater bands in the first zone to initially melt the material until the shear heating starts. For injection blow molding or injection stretch blow molding there is still a considerable need to input heat energy through barrel heaters. In either case, if barrel heaters are used they should be set up to give good heat transfer to the actual barrel.

The parison, the pre-form before the blowing operation takes place, often exceeds the weight of the final product by up to 40%. Any trimmed materials (tops and tails) can be recycled and recovered but the energy used is lost forever. Large tops and tails cost real money even if the material is recycled. Improved control of the parison and final product size will improve energy and process efficiency.

Regranulation should be done off-line (at night) to minimize energy costs, but first minimize tops and tail production - reduce and then recycle.

Develop start-up and shut-down procedures to save energy and time. It is not practical to shut down the extruder when it is not producing for a short time. But shutting down hydraulic systems can give considerable energy savings. Start-up procedures and sequencing can be set to bring energy demand online at the best possible time, i.e. heaters, until they are stabilized, hydraulics and finally the extruder drive. Similarly shutdown procedures can be developed to switch off the energy intensive areas of the machine.

---

[5] Courtesy of Dr. Robin Kent, Tangram, Ltd. This excerpt was taken largely from *"Energy efficiency in plastics processing – Practical worksheets for industry – Energy worksheets 1-12,"* Kent, Dr. Robin, Tangram Technology Ltd, 2005 (www.tangram.co.uk)

Ancillaries

Parison forming must be complete before the outside surface chills and stops surface texture formation. The compressed air pressure for blowing should be just sufficient to form the parison before chilling, but it can then be reduced to hold the parison against the mold surface. Maintain air pressures for blowing or holding at the minimum necessary pressure.
Minimize the melt temperature to the level needed. Most of the heat put in during the melting stage must be removed before the product is released from the die. Since product cooling time is about two-thirds of the cycle time, reducing melt temperature saves energy in heating and cooling and reduces the cycle time.

Chillers use large amounts of energy. Keep air out of lines by sealing, degassing and pressurizing the water cooling system. Cooling is most efficient with good contact between the parison and mold. Contact should be maintained by the air-feed during cooling.

Hydraulic systems for mold closing should be matched to the demand (blowing pressure x projected area) to reduce energy use and the hydraulic oil should be de-aerated on a regular basis to improve the efficiency of the hydraulic system. The hydraulic fluid should also be kept at a steady temperature to improve the process control and prolong the life of the oil. This is often done by running a chilled or controlled temperature water line through the hydraulics to cool, or at least control, the oil temperature.

Blow Molding 1 – Pulse Cooling

Best Practice	Pulse cooling is an electronic monitoring and mold temperature control system designed on the basis of on-demand cooling medium. The mold is retrofitted with a number of sensors at critical locations that actuate the cooling medium and allow for continuous flow until the proper temperature is achieved.
Primary Area/Process	In the main production facility, the device is adjusted to the mold which is placed into the press for production.
Productivity Impact	Productivity increases resulting from less low quality product.
Economic Benefit	The cost of this system, which includes the cost of the pulse system and retrofitting it to the mold, is estimated at $7,500. A typical payback is one year. The economic benefit is related to reduced water and energy requirements.
Energy Savings	Proper installation and operation of the system can lead to water and energy savings of up to $8,000 dollars annually.
Applications & Limitations	The molding process must be analyzed while designing the proper cooling cycle. This technology is most appropriate for new molds and when the design evaluation is based on heat transfer simulation modeling.
Practical Notes	The modification of the mold and placement of the sensors are associated with high cost. The technology is not suitable for a low-run production or mold with limited life expectancy.
Other Benefits	This best practice significantly reduces cooling water requirements. It also reduces wastewater.
Stage of Acceptance	This is an underutilized technology that has been around for over 10 years. A number of published studies indicate its usefulness.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Blow Molding 2 – Match Blow Former Equipment to Material

IMPROVES PRODUCTION

Best Practice	Blow forming is one of three common techniques for producing hollow structures. Blow forming is accomplished through extrusion or injection, based on material, design, and production requirements. The industry does not provide clear guidance on which process best fits a specific product. Assessing and selecting the best polymer based on performance as well as the polymer's behavior while heating, forming and cooling can improve production substantially.
Primary Area/Process	Heating, forming and cooling processes in blow forming.
Productivity Impact	Productivity increases since less low-quality product is produced
Economic Benefit	Service for this type of project can be rendered from outside sources with investment as low as $3,000 and is cost effective. Reduced material and energy costs make payback within one year.
Energy Savings	Energy savings depend on proper machine set up, the heating and cooling system selected, and the implementation of proper controls.
Applications & Limitations	The use of this system, such as pulse cooling, can benefit any blow former with dynamic heating and cooling needs. Limitations for this best practice include high initial cost and the need for mold modification.
Practical Notes	Testing can often be done in a laboratory, such as at the Center for Plastics Processing Technology at UW-Platteville.
Other Benefits	Thermoplastic parts such as a blow part always need to be cooled. Therefore, the system requires a considerable amount of water. This best practice also reduces cooling water requirements.
Stage of Acceptance	This is an underutilized technology that is not widely under-stood.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

Blow Molding 3 – Implement Proper Die Design

IMPROVES PRODUCTION

Best Practice	Die design is perhaps one of the most important factors in producing a quality blow-forming part. Proper die design can improve productivity, reduce scrap rate and result in energy savings.
Primary Area/Process	This best practice is implemented in the mold design and in the production area (verification).
Productivity Impact	A reduction in the volume of rejects improves productivity per unit of time and input.
Economic Benefit	This best practice requires appropriate training of the mold designer. Payback can be almost immediate.
Energy Savings	Reduction in rejected product can reach 10% in the blow forming industry. Energy used to produce rejects is wasted energy. Therefore, energy savings are tied directly to the reduction in rejects. The potential for energy savings along with material and manpower savings can exceed $10,000 annually.
Applications & Limitations	The benefits are large for new products in the design stage and not as significant for on-going products with limited production rates. Application to complex old molds with short run production is limited.
Practical Notes	None.
Other Benefits	This technology reduces the scrap rate, thereby reducing solid waste that would be sent to landfill, recycled or burned. This technology also reduces the need for regrinding and reproduction of molds.
Stage of Acceptance	Rejected product is costly and wasteful. A bad design has potential for a higher rejection rate. The mold design must be done by experienced personnel with good understanding of materials, processes and access to updated technology.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

Blow Molding 4 – Add Performance-Enhancing Plastic Compounds to Molding Materials

IMPROVES PRODUCTION

Best Practice	The addition of performance-enhancing plasticizing compounds to blow molding materials reduces the processing temperature and can reduce heating energy cost.
Primary Area/Process	This best practice is implemented in the material acquisition, engineering, quality control and production areas.
Productivity Impact	Reduction in processing time increases productivity.
Economic Benefit	Payback is immediate and can be verified with little investment. The price difference between the polymer and plasticizers is small.
Energy Savings	The benefits highly depend on material, machine size, production rate and others processing factors. For a blow forming with two inch screw, the potential in energy saving can exceed $15,000 annually.
Applications & Limitations	The application has potential for broad implementation. The compatibility of materials, additives and product requirements pose real limitations.
Practical Notes	The plasticizers are polymer additives, which assist material melting by reducing the melt temperature. This best practice has been widely used in injection molding, but limited in blow molding.
Other Benefits	Processing polymer at lower temperature reduces the heat degradation, improves quality, increases melt strength and allows for larger parts.
Stage of Acceptance	The role and contribution of additives in injection molding process is well established and documented. Although the principles have been established and documented, acceptance is limited by the tendency of blow formers to adhere to older proven techniques.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

INJECTION MOLDING

The typical cost of energy for a molding is 4% to 5% of its total cost. This portion increases rapidly with rising energy prices. Over 90% of the energy costs in injection molding are accounted for by electricity. This makes electricity purchasing very important for molders and costs can be significantly reduced by good purchasing and operational controls.[6]

Molding machines

As with most machines, the initial cost of a molder will be less than the cost of energy used during its lifetime. The energy cost will be even more for machines that are not energy efficient. Select new generation machines that have proven energy efficiency and can reduce product costs by more than 3%. Choose the right type and size of machine for the job and match it to the product. Using large machines for small products wastes energy and material.
Control operating conditions to meet design conditions since efficiency is lost as the operating conditions move further away from design.

Electric motors account for 60% of the electricity used in molders and the molding cycle causes intermittent, variable loads with power factor values in the region of 0.7. Power factor correction equipment can increase the power factor to greater than 0.95.

Controlling the start-up sequence of machines can trim energy costs with no negative effect on production. On the other hand, starting several machines at the same time will increase peak demand and power costs. Machines use energy when idling and can range from 52% to 97% of full consumption. Consider turning off machines that idle 20 to 45 minutes. Consider this especially for barrel heaters, cooling fans, cooling water pumps and compressed air.

All electric machines are an energy efficient solution and can both reduce energy use and make computer control easier and more direct. On conventional machines the hydraulic systems provide peak power for a very short time and the hydraulic system is overrated for most of the time. The use of accumulators for rapid hydraulic energy release can significantly reduce the hydraulic system size.

Barrel insulation is a proven method for reducing energy losses from plastics processing machinery and for producing a more stable process that enhances product quality and output. The positive aspects of barrel insulation are:

- Start-up times are shorter as the barrel gets to temperature quicker
- The energy used in heating is reduced by 7% to 25% of the total power usage of the machine
- The consistency of processing is improved
- A more stable environment for heating is created and high temperatures near the machine are avoided
- The health and safety risks associated with hot barrels are reduced

[6] Courtesy of Dr. Robin Kent, Tangram, Ltd. This excerpt was taken largely from *"Energy efficiency in plastics processing – Practical worksheets for industry – Energy worksheets 1-12,"* Kent, Dr. Robin, Tangram Technology Ltd, 2005 (www.tangram.co.uk)

The negative aspects of barrel insulation are:

- Insulation can take time to fix and set-up
- Damage occurs easily during changeovers and become ineffective. Checks on barrel insulation and correct fitting should become part of the machine setting process. Any defects or damage should be noted and rectified as with any other machine concern.
- When changing materials it can take time for the barrel to cool down

Molds

Product cooling can take more than 50% of the cycle time. Efficient cooling can greatly reduce both cycle time and energy usage. Maintain cooling water at the maximum temperature. Remove air from the cooling system to improve cooling effectiveness. Heat recovered from hydraulic systems and chiller units through heat exchangers can be used to provide space heating for offices and other areas with reasonable payback.

Use the rapid tool exchange system. Reduce tool change times to reduce idling time and avoid energy waste. Coordinate tool change times closely with production schedules.

Injection Molding 1 – Replace Hydraulic Machines with All Electric

Best Practice	Compared to all hydraulic machines, all electric injection molding machines are less expensive to operate, quieter, produce more consistent parts, allow fewer rejections and are cleaner since they do not use oil.
Primary Area/Process	Injection molding.
Productivity Impact	More consistent production of parts and reduced scrap. Machine movements can be integrated directly with controls to achieve improved machine set-up, adjustment and process control. Improved control means that process movement and shot weights are much more accurate than conventional machines. Increased precision improves product quality, reproducibility, monitoring of process parameters and mold protection. Cycle time can be reduced up to 30% with no loss of product quality.
Economic Benefit	A recent Focus on Energy study shows a $15,000 annual energy cost savings for a five year return for a new 550 ton all electric press, *based only on machine energy.* Production gain benefits should also be considered.
Energy Savings	The above study showed annual energy savings of an estimated 300,000 kWh with 5,000 annual hours of operation. Demand dropped from about 75 kW to 15 kW. Typical applications can reduce energy costs by 30% to 60% for a mold.
Applications & Limitations	At the time of printing this guidebook, all electric machines are available from 50 to about 1,100 tons.
Practical Notes	While all electric presses offer numerous benefits, they do not, at present, offer the "robustness" of all hydraulic presses. This may be significant and should be addressed when selecting an all electric machine. An example is a press that must process a variety of materials at significantly different operating conditions.
Other Benefits	Shorter cycle times are possible by using parallel operations (e.g. opening and ejection at the same time) to further trim energy consumption and increase productivity. The need to cool the hydraulic system is eliminated. Overall, all electric machines have lower failure rates and are easier and cheaper to maintain and repair than conventional machines.

	All electric machines use less water depending on the product, and water consumption can be cut by up to 65%. Electric demand reduction from all electric versus hydraulic presses is significant.
Stage of Acceptance	This technology is gaining acceptance. In spite of proven performance, all electric injection molding machines have been slow to penetrate the market. The cost difference between all electric and hydraulic machines is decreasing rapidly.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

Additional notes on All Electric vs Hydraulic Injection Molding

The European study discussed in the management best practices section also provided SEC information on the benefits of using all electric machines for injection molding.[7] The results are from a sampling of 165 facilities, two-thirds of which are injection molders. The table shows that even those facilities with a mix of electric and hydraulic far out perform those using only hydraulic machines. Savings beyond 19% shown here could be achieved through conversion to all electric.

Site Specific Energy Consumption for Electric vs Hydraulic Injection Molding

Type of Injection Molding Facility	Specific Energy Consumption (kWh/lb of polymer)
Hydraulic Machines, only (91% of sample)	1.320
Both Hydraulic and Electric Machines (7% of sample)	1.070
Difference	0.249
Energy Savings as a Percent	19%

All electric injection molding machines can reduce energy use by 30% to 60% depending on the particular molding and the all-electric machine being used. Controlled trials carried out by many manufacturers show significant energy savings. These savings are achievable across a broad range of materials from PS to PC and across a range of material grades. Energy savings can be achieved even if the cycle time remains at that required for the conventional hydraulic machine.

Typical Recorded Energy Savings for All Electric Machines

Application	Typical Recorded Energy Savings
Medical product (inhaler)	58%
Medical product component	60% in PS (53% in PC - with same mold conditions)
Automotive product (connector)	62%
Automotive product (connector)	33%
Household product (shower panel)	55%
Cap stack tool	28% to 64%
Garden product (flower pot)	40%

In most cases, cycle times can be reduced by carrying out operations in parallel, such as clamping and injection and opening and ejection, that can save energy and increase productivity. Trials have shown that using all electric machines and optimized cycle times energy savings and productivity are maximized.

---

[7] *"Reduced Energy Consumption in Plastics Engineering - 2005 European Benchmarking Survey of Energy Consumption and Adoption of Best Practice,"* September 30, 2005

Injection Molding 2 – Pulse Cooling

Best Practice	Pulse cooling is an electronic monitoring and mold temperature control system designed on the basis of on-demand cooling medium. The mold is retrofitted with a number of sensors at critical locations that actuate the cooling medium and allow for coolant flow until the proper temperature is achieved.
Primary Area/Process	The main production facility, the device is adjusted to the mold which is placed into the press for production
Productivity Impact	Productivity increases due to consistency of product quality.
Economic Benefit	The cost of this system, which includes the cost of the pulse system and retrofitting it to the mold, is estimated at $7,500. A typical payback is one year. The economic benefit is related to reduced water and energy requirements.
Energy Savings	Proper installation and operation of the system can lead to water and energy savings of up to $8,000 dollars annually.
Applications & Limitations	The molding process must be analyzed during the filling and cooling cycle. This technology is most appropriate for new molds and most suitable when the design evaluation is based on heat transfer simulation modeling.
Practical Notes	The modification of the mold and placing the sensor are associated with high cost. The technology is not suitable for a low-run production or mold with limited life expectancy
Other Benefits	This best practice significantly reduces cooling water requirements. It also reduces wastewater.
Stage of Acceptance	This is an underutilized technology that has been around for over 10 years and a number of published studies indicate its usefulness.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

Injection Molding 3 – Variable Frequency Drives to Reduce Cycle Energy Use

Best Practice	In some cases, the cost of operating injection molding machines can be reduced by placing a variable frequency drive (VFD) on the primary hydraulic pump motor, reducing power use during idle and potentially during screw return.
Primary Area/Process	Injection molding presses
Productivity Impact	None
Economic Benefit	A 550 ton all hydraulic press recently metered by Wisconsin Focus on Energy was found to use an estimated 375,000 kWh per year. Assuming a savings of 35% and an electric rate of $0.055 per kWh, the cost savings would be $7,200 annually. At an estimated installed cost of $15,000 to $20,000 the return is 2.5 years. This does not include the reduction in cooling load. Paybacks reportedly range from two to three years depending on the application.
Energy Savings	Efficiency gains are typically reported to be on the order of 30% to 40%, excluding cooling load reductions that result from less heat going to hydraulic oil or the room. Assuming a savings of 35% the VFD and required controls would save an estimated 131,000 kWh per year.
Applications & Limitations	The best candidates are larger machines with long cycle times, long operating hours, long idle times and high screw recovery rates.
Practical Notes	Work closely with the supplier to install this technology – it is much more complicated than installing VFDs on water pumps. Operator interface and operational flexibility has been a significant problem in the past and must be understood by management and operators *up front* to avoid problems during processing. Ask the supplier how this issue will be addressed.
Other Benefits	Reduced cooling system loads and potentially improved employee comfort.
Stage of Acceptance	This technology is generally understood but problems related to operator interface and flexibility with older installations have caused skepticism.
Resources	There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

Injection Molding 4 – Variable Frequency Drives on Cooling Water Pumps

Best Practice	Current practice in injection molding requires that cooling water pumps move up and down their power curves depending on how many molding presses are on-line or in production. Fitting pumps with VFDs can align pumping with the most efficient point on the pump power curve.
Primary Area/Process	Primarily, in the cooling loops of injection molding processes, although application to thermoforming or other plastics production processes are possible.
Productivity Impact	No specific productivity impact currently known.
Economic Benefit	Paybacks for installing VFDs on mold cooling water pumps vary, ranging from two to four years. An evaluation of an 85.5 % efficient 7.5 hp mold-cooling water pump motor resulted in annual energy savings of $830 at $0.07/kWh, operating 5,000 hours per year. The estimated payback was 2.4 years.
Energy Savings	The energy savings and demand reduction for installing the VFD above was estimated at 11,482 kWh and 2 kW.
Applications & Limitations	While mold-cooling water systems have been addressed, tower water pumps are also candidates. Care must be taken with packed towers operated in freezing conditions if tower water supply pumps are fitted with a VFD. Reports indicate that a water flow rate lower than design can cause channeling due to freezing conditions to develop in the packing, potentially disrupting tower operation.
Practical Notes	Temperature control units usually require a minimum pressure difference and inlet pressure to function properly. Differential pressure controls can address this issue.
Other Benefits	No other specific benefits.
Stage of Acceptance	Use of VFDs is widely accepted, but many are unaware of the application to mold cooling loops in injection molding processes.
Resources	There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

Injection Molding 5 – Implement Proper Gate Design

IMPROVES PRODUCTION

Best Practice	The gate is the entry into the mold cavity and is the principle mechanism governing cavity filling both in terms of time and flow characteristics. Selecting the best gate location and gate design potentially reduces cycle times, improves productivity, reduces scrap waste and yields energy savings.
Primary Area/Process	This best practice is implemented during the mold design in mold making facility.
Productivity Impact	Improved product quality, reduced cycle time, minimized rejection rate and improved production rate.
Economic Benefit	Depending on the size of facilities services can be rendered from outside sources with minimal investment. Payback can be realized in the production of the first part.
Energy Savings	In injection molding with multi-cavity and high production rates, the number of parts produced can easily reach several millions. Reduction of the cycle time even by a fraction of a second can result in substantial energy savings and reduced costs.
Applications & Limitations	This best practice is not applicable to low-run production or where the production has already received a substantial investment in mold and mold production.
Practical Notes	The application is more suitable to complex engineering parts with emphasis in part quality and part integrity.
Other Benefits	Reduced lead time, improved product quality and reduced scrap rate are among the major benefits of this technology.
Stage of Acceptance	Although new simulation software has changed the art of mold design to well-established science, a lack of understanding and unwillingness by industry to invest in this area has delayed its adoption.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

Injection Molding 6 – Add Performance-enhancing Plastic Compounds to Molding Materials

IMPROVES PRODUCTION

Best Practice	The role and contribution of additives in the injection molding process is well established and documented. A stream of new, performance-enhancing additives have been introduced into the market with little notice. These additives can reduce the plastic processing temperature and, thereby, reduce heating energy costs.
Primary Area/Process	This best practice is implemented in the material acquisition, engineering department, quality control and production areas.
Productivity Impact	Reducing the processing time increases the production rate.
Economic Benefit	Payback is immediate and can be verified with little investment. The price difference between the polymer and plasticizer is small.
Energy Savings	The benefits highly depend on material, machine size, production rate and other factors. The energy saving potential for an 80 ton injection molding with a 7.5 oz shot capacity can exceed $10,000 annually.
Applications & Limitations	The application has potential for broad implementation. The compatibility of materials and additives and product requirements may pose some limitations.
Practical Notes	The plasticizers are polymer additives, which cause a reduction in melt temperature.
Other Benefits	Processing polymer at lower temperature reduces heat degradation, improves quality, increases melt strength and reduces cycle time.
Stage of Acceptance	This practice has been widely used in injection molding, although not to its maximum potential.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville There are a number of commercial resources for this technology. Please contact one of the Wisconsin Focus on Energy representatives listed in Appendix C if you need additional information.

THERMOFORMING

In thermoforming a plastic sheet is heated to the processing temperature and forced to conform to the configuration of a pre-designed mold. The process is energy intensive with an estimated 90% of the electrical energy consumed by the electric heating elements. This makes performance of the overall electrical system very important to thermoformers. The use of proper equipment, materials, processing conditions and, most importantly, the selection of proper radiant heating elements can significantly reduce energy usage and operating costs.

Thermoforming Presses

The initial capital cost of a thermoforming machine is less than the cost of energy used during the press lifetime. This difference is even more pronounced in the heating oven where the formation of the proper radiation characteristics is a function of the element's surface condition. The energy efficiency of the process declines significantly when the heating elements are inefficient or not compatible with the processing materials. Best practice options include:

1. Select a more efficient type of heater that has the potential for substantial energy savings. In some cases the energy savings can exceed 20%. A proper heating element will be energy efficient and compatible with the processing material. The radiation temperature characteristic of the plastic material makes it necessary to select the proper heating process parameters and equipment. This requires an understanding of the process and the implementation of proper controls to achieve the optimum condition.

2. Installing radiant heating elements, such as ceramic, Pyrex and quartz are energy efficient solutions for thermoforming ovens and, with proper zone design, they can reduce energy use. The zoning also allows for computer interface making it easier to achieve more control over material distribution. Their potential benefit can vary from one process to another and from one material to another. One must consider the:
   - Physical and chemical nature of the material
   - Frequency of change in materials
   - Thickness of material
   - Processing environment and conditions

3. Heat transfer to the mold improves during formation and can be controlled by pre-seating the cooling medium with the mold. The part must be cooled to lower than its heat distortion temperature (HDT). The speed of achieving this temperature can affect the internal stress of the product as well as energy consumption. The problem can be minimized by selecting the heating elements with proper wattage, but with minimum watt-density, and keeping the heating elements clean and in the best processing condition.

4. Roll-fed thermoforming, particularly inline thermoforming, is a continuous process. The pelt/sheet transfers from one station to another via a mechanism operated by electric motors. The energy consumption of electric motors potentially can account for 30% of the electricity used in this process. Selection of the proper electric motors, with power factor correction equipment, can increase the power factor from 0.7 to greater than 0.95 with a payback of less than one year.

5. Controlling the start-up sequence of machines can trim energy costs with no negative effect on production. On the other hand, starting several machines at the same time will increase peak demand and power costs.

Molds/forms

An equilibrium rule governs the thermoforming process – particularly for roll-fed thermoforming. The plastic sheet indexes from the roll into the oven and advances into the forming and trimming station. Hence equal time is available for heating and cooling. The heating temperature changes from room temperature to processing temperature and the cooling temperature change is from processing temperature to just below the heat distortion temperature. A cold plastic sheet cannot form. However, a sheet that is too hot will deform as it removes from the mold. Hence the cooling medium is critical in the production process. Efficient cooling can greatly reduce both cycle time and energy usage.

Heat recovered from the oven and other heat generating components can be used to preheat the plastic sheets and rolls and to provide space heating for offices and other areas. Insulating the thermoforming oven may also aid in controlling internal heat and can save large amounts of energy.

Thermoforming 1 – Upgrade Thermoformer Element

Best Practice	Retrofit older thermoforming machines using “cal-rod” heaters with more efficient ceramic or quartz elements and improved zoning capability and controls. Improvements of 30% to 40% are possible depending on the material’s energy absorption and subsequent improvements in productivity.
Primary Area/Process	Continuous roll-fed, single and double station thermoformers are often good candidates.
Productivity Impact	Quartz and ceramic heating elements offer more efficient radiant heating. As a result, the time to reach the required sheet temperature can be reduced, allowing an increase in throughput per unit of time. Cycle time can also be cut in half.
Economic Benefit	The payback for a good application ranges from two to four years *on energy alone*. A recent application on a Brown roll-fed machine showed an estimated equipment cost for quartz heaters and controls to be $20,000. Both energy and production benefits were anticipated.
Energy Savings	Energy savings can vary widely but reductions of 30% to 40% for heater energy use are common. Reduced cycle time saves additional energy on single station thermoformers.
Applications & Limitations	Continuous roll-fed, single and double station thermoformers that use cal-rod ovens with little zoning capability are the most favorable.
Practical Notes	Since thermoforming processes rely primarily on radiant heat, the type of material being processed is important. Where many materials are processed on a single machine, it may be better to accept less efficient cal-rod heaters to maintain flexibility. Use an infrared (IR) camera to help determine if one machine is better suited for a particular material. IR cameras also allow observation of sheet temperature profiles.
Other Benefits	Supplying more radiant heat to the plastic part means that less convective heat is available to enter the work room. This may result in less air conditioning and process cooling demand. In any case, employee comfort may also be improved.
Stage of Acceptance	This concept is proven, but many are unaware of its benefits.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representatives listed in Appendix C for more information.

Thermoforming 2 – Design New Thermoformer with Energy Efficient Element

Best Practice	Thermoforming is a plastic production technique in which a heated plastic sheet is forced to conform to a mold. It is a highly energy intensive process. Replace conventional cal-rod heating elements with more efficient radiant heater elements within the oven for substantial energy savings.
Primary Area/Process	This best practice is implemented through design of the oven of a thermoformer in engineering.
Productivity Impact	Productivity improves from the reduction of rejected parts, particularly for highly linear and highly crystalline polymers.
Economic Benefit	The cost to replace convective cal-rod heaters with more efficient radiant heaters of proper characteristic can be $6,000 to $10,000. Including productivity benefits, payback is potentially less than a year.
Energy Savings	Proper installation and operation of the system can lead to energy savings of $4,000 to $8,000 dollars annually.
Applications & Limitations	Successful implementation of this technology highly depends on the compatibility of the emissivity of the heating elements and the absorption characteristic of raw materials.
Practical Notes	This best practice requires an evaluation of heater types and of plastic compound material properties. It may not be applicable to every condition.
Other Benefits	An increase in quality and the ability to process difficult polymers are additional benefits of this technology.
Stage of Acceptance	The radiant heaters have been around for a long time. Implementing these heaters in thermoforming began in the early 1990's. Due to the complexity of material and energy absorption, the technology has not yet achieved wide acceptance.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Thermoforming 3 – Select Radiant Heater Retrofit to Match Plastic Compound Thermal Properties

IMPROVES PRODUCTION

Best Practice	Infrared heaters can save a substantial amount of energy when their emissivity is matched with the absorption characteristics of the plastic sheet.
Primary Area/Process	This best practice is implemented in the heating oven of a thermoforming press on the production floor.
Productivity Impact	Improves product quality (and thereby reduces low quality product) by reducing the exposure of the plastic sheet to a high temperature environment.
Economic Benefit	Radiant heaters, when their use is appropriate, provide a substantial benefit. The cost depends on the type of radiant heater (ceramic, glass, quarts...) selected, the size of the heating panel, the controller, the size of the oven, and other factors. Radiant heater costs start at $7,000. The payback for this investment is estimated at 18 months.
Energy Savings	Proper implementation of radiant eaters can cut energy costs by 50% and increase productivity by 76%.
Applications & Limitations	The maximum benefit from this technology can be realized by a thermoformer which utilizes the same type of plastic over a long period. The technology can pose a serious limitation for custom thermoforming.
Practical Notes	This best practice requires an evaluation of heater types and of plastic compound material properties. The IR camera can be used to help determine if one machine is better suited for a particular material type than another.
Other Benefits	Increased productivity, improvement in product quality, and a high level of constancy are additional benefits.
Stage of Acceptance	The technology has been around since 1950's. The complexity of matching heater emissivity and plastic absorption curves has been a barrier to adoption of this technology.
Resources	For information on this technology see: Center for Plastics Processing Technology, UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Thermoforming 4 – Apply Proper Part Design

IMPROVES PRODUCTION

Best Practice	A properly configured thermoform part can be produced by using different mold configurations such as male, female, matched mold and others. The use of simulation modeling software to select the proper technique and design criteria can simplify the production process and reduce cycle time and energy costs.
Primary Area/Process	This best practice is implemented in the design stage of mold building in the mold production area of a thermoforming facility or mold maker.
Productivity Impact	Proper part design can simplify production and lower manufacturing cost. It can also improve part quality, increase consistency and reduce rejection rates.
Economic Benefit	Payback varies from one mold to another and is affected by a number of parameters. For many molds the payback is immediate.
Energy Savings	Due to variation in part size, shape and material used, energy savings will vary by mold.
Applications & Limitations	This technology is only applicable when a new mold is produced or when a new mold for continuing production part is required.
Practical Notes	This best practice requires design knowledge and tools, including simulation models for part design. The mold must be tested prior to production. Producing a good part from a bad mold is near impossible. A well-conceived and designed mold is the first step in process efficiency.
Other Benefits	Reduced lead time.
Stage of Acceptance	Although the cad-cam system has a long history of use in mold making for thermoforming, the use of simulation modeling has not been received well by the industry.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Thermoforming 5 – Select the Sheet with Proper Physical and Chemical Characteristics

IMPROVES PRODUCTION

Best Practice	The processing temperatures required for plastic sheets cover a wide range – from about 325°F for acrylics to over 700 °F for high-heat engineering plastics. Their specific heats range from 0.2 Btu/lb-°F to ten times that amount. Therefore, selecting the plastic sheet with the proper physical and chemical characteristics is very important. Selecting a sheet with lower process temperature and specific heat requirements can save a substantial amount of heating energy.
Primary Area/Process	This best practice is evaluated and specified in the design and engineering areas and implemented on the production floor.
Productivity Impact	The best plastic is not always the most expensive. The property of a material is application dependent. Selection of the best sheet can improve production.
Economic Benefit	In the right instances, payback can be immediate. There is also potential for substantial savings in material costs.
Energy Savings	Energy savings vary with application.
Applications & Limitations	The application may be limited by customer specification or previous purchase of materials.
Practical Notes	This best practice requires an evaluation of heater types and plastic compound material properties. IR cameras allow observation of sheet temperature profiles, which can be used for process analysis.
Other Benefits	Improved quality, reduced cycle time and lowered manufacturing cost.
Stage of Acceptance	Cost competition is driving manufacturers to search for materials that save on process costs and meet customer needs.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Thermoforming 6 – Coupling Extruder to Thermoformer

IMPROVES PRODUCTION

Best Practice	This production technique couples extrusion with thermoforming. As it leaves the extrusion press the extrudate is thermoformed. This technique has the potential to reduce energy consumption for thermoforming significantly.
Primary Area/Process	This best practice encourages consolidation of extrusion and thermoforming processes in a single production line on the production floor.
Productivity Impact	This combined process is, perhaps, the most efficient of its kind today, reducing lead times and space requirements, while improving quality, profitability and productivity.
Economic Benefit	The payback can be as short as six months.
Energy Savings	In conventional thermoforming, plastic pellets undergo heating and cooling to produce sheet plastic. The plastic sheet goes through a second heating and cooling cycle to produce the thermoformed part. Since in-line thermoforming, the raw materials go through heating and cooling cycle once, creating the potential for energy savings up to 50%.
Applications & Limitations	This practice is best applied to a single material, continuous production process.
Practical Notes	This best practice requires the redesign of production to combine the two processes. The decision to use this technology requires serious scrutiny and commitment from management.
Other Benefits	Saves on space and transportation. Reduces investment in non-productive equipment. Improves productivity.
Stage of Acceptance	Acceptance of this technology is growing, but mostly in large corporations where significant support exists.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Thermoforming 7 – Infrared Scans of Inputs, Processes and Waste Streams

Best Practice	"Cal-rod" or tubular heaters are very common in thermoformer operations, particularly on older ovens. These "non-radiant" elements can be replaced with more efficient ceramic or quartz elements with savings of 30% to 40%. However, determining the potential savings prior to replacement is difficult without infrared camera (IR) technology because there is no other easy way to determine the fraction of energy used that is transferred as heat to the sheet.
Primary Area/Process	Roll-fed, single and double station thermoformers with cal-rod heaters are often good candidates.
Productivity Impact	The use of IR cameras can allow the optimization of existing thermoformer operations and proper matching of sheet material to a particular oven configuration. This can improve throughput.
Economic Benefit	The return on investment depends on whether use of the IR camera can increase confidence in energy and production cost savings estimates enough to justify changes.
Energy Savings	There are no *direct* energy savings from using the IR camera. However, if using it encourages replacement of cal-rod oven elements or helps to optimize throughput, energy savings of 30% to 40% of heater energy are achievable.
Applications & Limitations	Continuous roll-fed, single and double station thermoformers that use cal-rod ovens with little zoning capability are the most favorable.
Practical Notes	Since thermoforming processes rely primarily on radiant heat, the type of material being processed is important. IR cameras can be used to help determine if one machine is better suited for a particular material. This can also improve productivity. IR cameras also allow observation of sheet temperature profiles, which can be used for process troubleshooting.
Other Benefits	More efficient oven heating means less heat is lost to process and comfort cooling systems, reducing the cost of cooling system operation.
Stage of Acceptance	This concept is proven, but many are unaware of its benefits.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

EXTRUSION

Extrusion is both a final forming process and an intermediate process for other processing techniques such as injection molding, blow molding and film blowing. Efficient operation of extrusion screws is therefore essential to much of the plastics processing industry. For profile extrusion the energy used to drive the extruder itself accounts for 50% of the total energy to produce the part. Ancillary end uses account for the remaining amount. Surveys show that a typical company can trim energy use by 10% without major capital investment.[8]

The Extruder

Energy efficient extruders may cost more, but they yield rapid returns on investment. Options may include high efficiency AC motors and variable frequency drives (VFDs).

Use the right extruder for the job. Check the screw diameter and design to make sure they fit the polymer and the product. Match the extruder size to the product profile to minimize waste. Set the extruder to run at its most efficient speed (usually maximum design speed) and control the screw speed to give an extrusion rate as close to the maximum as possible while maintaining good product quality.

Motors run most efficiently close to their design output - a large motor at part load is less efficient than a small one at full load. Size and control the motor to match the torque needed by the screw.

Optimized extruder speed maximizes heat transfer from mechanical work and minimizes the amount of electricity needed. Doubling the rotational speed of the extruder, as long as the downstream equipment does not limit output, can cut energy consumption by nearly 50%.

Accurate temperature control is also needed for good extrusion - excess temperatures waste energy. Keep the polymer close to the optimum processing temperature. Check the controls to make sure that the heating and cooling are working efficiently together.

The Ancillaries

Once the extruder is operating at optimum conditions the need for downstream cooling and calibration is minimized. Next steps include:

- Setting the maximum cooling water temperature to achieve the maximum acceptable extrudate temperature after cooling. Check that cooling water is treated, chilled and distributed efficiently and is not circulating through idle calibrators.

- Checking that compressed air is generated and distributed efficiently at the minimum pressure needed by the process and is not supplied to idle machines.

- Checking that the vacuum supply is the minimum needed, that it is generated and distributed efficiently and that the vacuum supply is switched off when not needed.

---

[8] Courtesy of Dr. Robin Kent, Tangram, Ltd. This excerpt was taken largely from *"Energy efficiency in plastics processing – Practical worksheets for industry – Energy worksheets 1-12,"* Kent, Dr. Robin, Tangram Technology Ltd, 2005 (www.tangram.co.uk)

Extrusion 1 – Post-Heating of the Extrudate

Best Practice	Extrusion is the restriction of high pressure polymer flow to conform to the configuration of a die and results in orientation of molecules to the direction of flow. The action of "take-off" rollers causes further orientation of molecules in the extrudate, leading to an undesirable non-uniformity of physical and mechanical behavior. Reducing flow velocity and the speed of the take-off-rollers can reduce molecular orientation; but it also reduces output and increases the energy consumption per part. This best practice recovers heat loss from the barrel to re-heat the extrudate, allowing the plastic molecules to reorient themselves, without having to reduce production rate.
Primary Area/Process	The production line on the production floor.
Productivity Impact	The strength and failure mechanism of a plastic component depends highly on the orientation of molecules. The strength of molecules in the direction of the length can be 20 times the strength holding two molecules together. Many extrusion products such as household piping, require a secondary operation to overcome this weakness. Rearranging the outer layer of extrudate by applying heat can reduce the costs of the secondary operation.
Economic Benefit	Paybacks for good applications range from two to three years based on energy savings alone.
Energy Savings	Energy savings vary widely depending on the amount of benefit available from reducing energy from the secondary operation.
Applications & Limitations	Extrudate under high pressure such as household piping, air pressure delivery system and other pressurized systems are the most favorable.
Practical Notes	Pay special attention to the system design since exposing the heated extrudate to higher temperature can increase the cycle time and cause a reduction in product quality.
Other Benefits	Arranging molecules in random direction improves product quality and allows the use of plastic extrudate as a substitute for more costly, energy-intensive products such as metal piping.
Stage of Acceptance	This technology has been investigated and applied in limited applications.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Extrusion 2 – Implement Proper Die Design

IMPROVES PRODUCTION

Best Practice	Extrusion is a plastics process commonly used to produce a structure of generally constant cross-sectional area, but with different lengths such as sheets and profiles. The design of the die, the opening which defines the general shape of the part, greatly affects processing characteristics and final product quality. Proper die design and verification using simulation software can improve productivity, reduce scrap rate and yield energy savings.
Primary Area/Process	This best practice applies to die design and verification using simulation packages.
Productivity Impact	A reduction in the volume of rejects, results in improved production rates.
Economic Benefit	Since this best practice requires appropriate training of the die designer, payback is almost immediate.
Energy Savings	A reduction in rejected product can reach 5% or more depending on the complexity of the profile and profile tolerances. The energy wasted in producing rejects is avoided. Potential energy savings along with savings in material and manpower can exceed over $10,000 annually.
Applications & Limitations	The benefits are highest for new products in the design stage and lowest for on-going production with a limited production rate.
Practical Notes	Application to complex profiles and the short run production is limited.
Other Benefits	This technology reduces the complexity of the die, reduces the scrap rate, and thereby reduces the recycling rate.
Stage of Acceptance	Although simulation modeling provides a clear visual picture of the flow characteristics of materials in the die and predicts potential problems, the industry relies almost completely on the experience of die makers and has not eagerly adopted this promising technology.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Extrusion 3 – Add Performance-Enhancing Compounds to Materials

IMPROVES PRODUCTION

Best Practice	When extruded materials depart from the gate they must have the same temperature, pressure and flow rate in order to produce a high quality product. Temperature can be modified using plasticizing compounds; flow rate can be facilitated using lubricating compounds. Changing the cross section of channels can improve the flow rates. The selection and proper use of these additives can affect processing characteristics, reduce the rejection rate, improve product quality, increase production rates and save energy.
Primary Area/Process	The material acquisition, engineering department, quality control, and production areas.
Productivity Impact	Reducing the cycle time and amount of low quality product increases productivity.
Economic Benefit	Payback is immediate and can be verified with little investment. Cost accounting methods sometimes interfere with realizing the true potential of additives. Purchasing agents, tasked with keeping material costs down, are not rewarded for spending money that may result in significant savings for operations, which improves the bottom line.
Energy Savings	The benefits depend highly on material, machine size, production rate and other factors. For a 2.5 single screw extruder the potential in energy saving can exceed $6,000 annually.
Applications & Limitations	The application has potential for broad implementation. The compatibility of materials and additives, as well as product requirements may pose some limitations.
Practical Notes	The plasticizers are polymer additives, which cause reduction in melt temperature. The lubricants are polymers such as polyethylenes which reduce molecular friction during processing
Other Benefits	Processing polymer at lower temperature reduces heat degradation, improves product quality, increases melt strength and reduces cycle time.
Stage of Acceptance	Although not implemented to its fullest potential, this practice has been widely used in injection molding.
Resources	For information on this technology see: Center for Plastics Processing Technology – UW-Platteville A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Extrusion 4 – Converting DC Drives to AC Drives

Best Practice	Extruders are often equipped with DC drives and motors due to the constant torque requirement of the extrusion process. Modern "vector" AC drives can provide constant torque over a broader operating range than previously possible and provide significant energy savings.
Primary Area/Process	Extruders that use DC drives and motors. However, any DC drive/motor combination is a potential candidate.
Productivity Impact	None currently known.
Economic Benefit	The economic benefit is related to energy efficiency, the reduction of power factor penalties and reduced maintenance.
Energy Savings	*Energy efficiency* gains are usually available if the DC drive is operating at reduced speeds. Energy efficiency may improve by up to 10% when including the elimination of the separate cooling fan required for DC motors.
Applications & Limitations	This concept is most feasible on DC drives and motors operating at much less than 100% of full speed since DC-drive motor efficiency drops more as speed is reduced. Larger systems (500-hp) offer less energy efficiency gain than smaller systems (5-hp).
Practical Notes	Drive selection is very important and in some cases *up sizing* may be necessary. Also, try to avoid *downsizing* of motor and drive capacity unless it is certain that the lost capacity will not be needed in the future.
Other Benefits	Beyond saving energy, conversion to AC drives and motors can avoid DC motor maintenance. AC drives also correct power factor and may reduce penalties for low power factor due to using DC motors and drives. Under part load, DC-drive motor combinations can cause power factors as low as 20%.
Stage of Acceptance	Appears to be gaining acceptance.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

GENERAL FACILITY

The technical best practices found in this section primarily address production processes and applications that are generally unique to the plastics industry. **Appendix A** provides a **checklist** of the technical best practices in this section with payback estimates. A plastics facility manager can use this list to identify and track the status of these best practices with this checklist.

Appendix B at the end of the guidebook presents additional best practices for common support systems found in most industrial facilities but not described in any of these sections (lighting systems, motors, compressed air systems, etc.). Facility managers should also consider opportunities in these common systems for reducing energy costs.

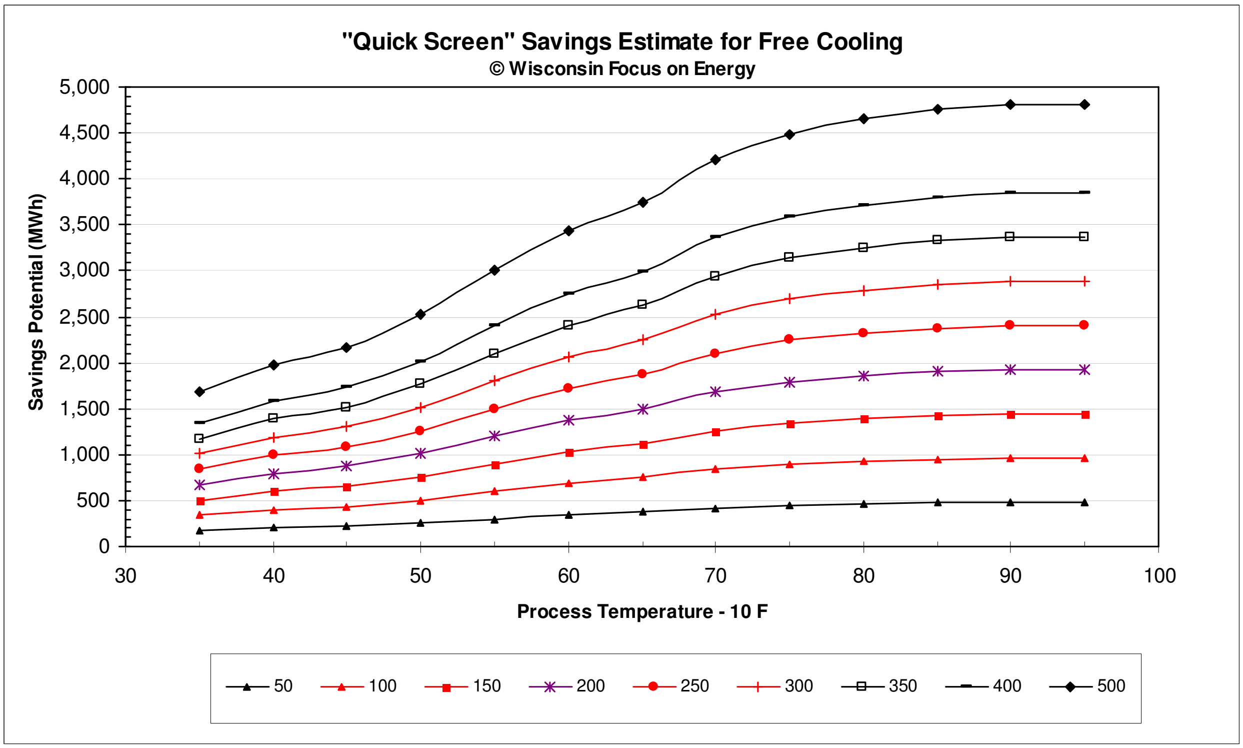
General 1 – Free Cooling in Plastics Production

Best Practice	Free cooling, also known as “air blast cooling”, is the use of the cool ambient conditions to remove heat from process streams *without* the use of a chiller.
Primary Area/Process	Free cooling is not process specific.
Productivity Impact	None unless free cooling adds useable cooling capacity.
Economic Benefit	The benefit come from taking the chiller off line and depends on the chiller load, electric rate and the number of hours available for free cooling. Installed cost typically ranges from about $500 per ton for small (50 to 75 ton) systems to about $325 per ton for systems larger than 400 ton. Return on investment is two to four years in the upper Midwest.
Energy Savings	The annual energy savings depends primarily on the hours available for free cooling, which is dictated by process temperature requirements. The following can be used as a guide to determine energy savings potential assuming installation on fully loaded chillers in Madison, Wisconsin, process operation 24/7 and a process cooling temperature of 55°F: • 50 ton cooling: 217,000 kWh • 400 ton cooling: 1,736,000 kWh
Applications & Limitations	Free cooling benefits are limited primarily by process temperature requirements and the *actual load* on the chillers. Free coolers are available for capacities as low as five kW with no effective upper limit as units can be linked together to provide greater cooling capacity.
Practical Notes	If heat is being recovered from the chiller, this must be accounted for in evaluating project economics. Free cooling systems should be sized to match the installed *capacity* on a given cooling loop to maximize benefits.
Other Benefits	Free cooling can prolong the life of chillers since they are off when the system is in full free cooling mode.
Stage of Acceptance	This technology is not widely understood and therefore has low market penetration to date.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

ADDITIONAL NOTES ON FREE COOLING

Low ambient temperatures in Wisconsin and higher flow temperatures used in plastics processing mean that free cooling often can reduce energy costs considerably. Free cooling pre-cools the return water from the process and significantly reduces both chiller loads and energy use.

If the ambient temperature falls to 2ºF or more below the return water temperature, then the return water is diverted through the free cooler. The more the ambient temperature is below the return water temperature, the greater is the free cooling effect. It is possible to switch off the main chiller when the ambient temperature is 5ºF below the return water temperature.



To determine your savings potential, subtract 10^{o}F from your process temperature requirement and locate the value along the x-axis. Move vertically upward to your estimated chiller load and horizontally to the left to determine the potential savings. Therefore, "facility savings" equals:

Savings potential x (chiller hours / 8760) x 1000 x electric rate in $/kWh.

The simple return equals:

(Chiller nameplate capacity {TR} x (-0.4125) + 516.61) x chiller nameplate capacity {TR} / facility savings

Example: A 100 ton chiller loaded at 50% delivers chilled process water at 70^{o}F. The cooling system operates the same hours as the facility, 6000 hours per year. The electric rate is $0.045/kWh. From the chart, the savings potential = 340 MWh. The facility cost savings equals:

340 MWh x 6000 / 8760 x 1000 x $0.045/kWh = $10,480 / yr

The simple return is:

((100 TR x (-0.4125) + 516.61) x 100 TR) / $10,480 = 4.5 years

General 2 – Awareness of Energy Efficiency

Best Practice	User awareness of operation costs and understanding how, when and where equipment is operated can lead to significant energy saving and production improvement behaviors. Useful support tools include power meters and infrared cameras.
Primary Area/Process	Facility-wide. Awareness at all levels of management, accounting and operation with respect to process and ancillary operations provides the greatest benefit. Can be specific process equipment (molding machines, extruders, etc) or ancillary operations like compressed air and ventilation.
Productivity Impact	Awareness campaigns have resulted in numerous productivity improvements. Examples are setting molding temperatures at lower set points and diverting cooling capacity to reduce cycle times to other locations in the facility where it is needed.
Economic Benefit	Return on investment is usually less than one year with little to no capital cost. Additional economic benefit may come from quality and/or productivity improvements.
Energy Savings	Documented energy savings range from 3% to 15%. A reduction of only 3% for a facility with $100,000 in annual energy costs will save $3,000 per year.
Applications & Limitations	Often management support is *mandatory* to establish an effective awareness program, particularly where changes in process parameters are targeted. However, with management support, there is no limit to the application of effective awareness programs.
Practical Notes	Shifting the mindset to establish an effective awareness program may require outside assistance to get organized and started. Specifically, the use of IR cameras and metering can help analyze and optimize existing operations, including the proper match of sheet material to thermoformer ovens.
Other Benefits	May help reduce scrap waste and improve production.
Stage of Acceptance	This concept is proven, but true awareness programs are rare.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix C for more information.

Additional General Facility Best Practices

While plastics processors can save money in all areas of their operations, opportunities for investment in energy efficiency include:

- Diagnostic technologies that help match equipment to materials and products
- All electric injection molding machines
- High-performance heating technologies
- Optimizing process cooling systems
- Variable frequency drives
- Scheduling equipment warm-up time with the start of production to minimize idle time
- Matching equipment settings to process demands
- Polymer drying
- Polymer transport and conveyance

BASIC BEST PRACTICES

Conduct an initial site energy survey looking particularly on equipment with the largest electrical loads, including motors, lighting, heating and cooling. You can implement several procedures immediately with little or no capital cost:

- Infrared (IR) cameras can provide observation of temperature profiles, which can be used for process troubleshooting. They can find heat loss (and waste) and help the operator optimize existing operations. Return on investment depends on whether use of the IR camera can increase confidence in the estimates of energy savings and production benefits enough to justify changes. IR cameras can also be used to determine if one machine is better suited for a particular material.

- Determine which machines must be kept idling during non-production periods. Turn them off, with controls if possible, while not in production.

- Look for areas where no productive work is being done, but where machines are running and using energy, such as compressed air systems cycling during off-production times.

- Use variable frequency drives on cooling tower fans where savings can be large.

- Check for leaks in compressed air systems. Consider controls, compressor staging, storage and variable frequency drives for variable loads. Make sure that compressed air is not being used for expensive applications (e.g., cleaning or drying) where a cheaper substitute is available. Size systems to meet productive loads and eliminate any unproductive uses.

- Make sure that motors are properly sized for their loads. An improperly sized motor will cycle frequently, creating higher potential for failure. Check to see if VFDs can be used where the airflow from fans is being throttled back with dampers.

- Look for and repair all water, air or steam leaks beginning with the largest.

- Make sure that thermal insulation on all machines is in good condition.

CHILLERS[9]

Thirty tons of cooling capacity uses an estimated 30 kW of electric power. Even a small plastics processing site may need a 60 ton chiller, costing over $20,000 per year to operate. Simple measures can improve chiller efficiency:

Cooling load

- Supply cooling only where needed
- Use the maximum possible water temperature; a 2ºF rise in the supply temperature reduces the energy required by 3%

System Optimization

- Use the most suitable refrigerant and optimize the system for high, part-load and winter efficiency, especially when chillers have been added to the system
- Balance pumps and chillers, and match them to the normal load (with controls to match a variable load)
- Check that pipe work and pumps are sized correctly for current demands
- Ventilate chillers to provide good airflow over the condensers
- Recover waste heat for space heating and hot water

Components & Sequencing

- Use scroll and screw compressors
- Avoid running chillers at low loads
- Use large evaporators and condensers and avoid direct expansion evaporators if possible
- Use variable speed drives (VSDs) for pumps and fans to match the output to process demands

Operation and maintenance

- Service chillers regularly and keep records of plant conditions
- Clean evaporators, air blast coolers and heat exchanger surfaces regularly
- Check flow/return temperatures and system flow rates to verify these are correct and optimized
- Keep systems gas tight and repair gas leaks
- Design molds and cooling baths or spray tanks to provide good heat transfer from the plastic to the cooling water
- Set all systems components to turn off automatically when not in use

---

[9] Courtesy of Dr. Robin Kent, Tangram, Ltd. This excerpt was taken largely from *"Energy efficiency in plastics processing – Practical worksheets for industry – Energy worksheets 1-12,"* Kent, Dr. Robin, Tangram Technology Ltd, 2005 (www.tangram.co.uk)

POLYMER DRYING[10]

Drying uses large amounts of energy and is necessary for processing hygroscopic polymers (those that absorb water) and for repeatable processing of non-hygroscopic polymers. If a polymer is not dried, any moisture present converts to steam during processing and creates surface marks and may even weaken the molded parts. Simple measures can achieve significant energy savings during drying.

Desiccant drying
Desiccant dryers pass moisture-laden air through a desiccant (a moisture removing material) to produce warm dry air, which is then passed through the polymer. The air then removes moisture from the granules and is recycled back to the dryer for further drying and use.

The desiccant has to be regenerated using a high heat cycle to remove the moisture that it has adsorbed. A typical dryer uses continuously rotating desiccant canisters or valve arrangements to cycle the desiccant through the drying and regeneration stages. The drying time depends on the type of material – hygroscopic polymers (such as PA, PET, ABS and PC) absorb water readily into the bulk material and the water becomes chemically bonded to the polymer chains. This type of material has a natural moisture content of up to 1% and will always require drying to be processed successfully. Typical drying times for these materials can be up to six hours.

Non-hygroscopic polymers (such as PE, PP and PMMA) do not absorb water but can pick up moisture on the granule surface in high humidity atmospheres. This type of polymer may require drying depending on the history of the material.

Exposing polymer at elevated temperatures can degrade properties, but in most cases the drying temperature is in the region of 180^{o}F.

Heat recovery from drying
Conventional desiccant machines do not recover the heat lost from the dryer during the process and often incur cooling costs. The latest machines use integral heat exchangers to recover heat from the exhaust air and recycle this back to pre-heat the cooler dried air from the desiccant dryer. This process can improve the heat balance so that up to 56% of the input energy is used to actually dry the polymer. This almost doubles the efficiency of the system and significantly reduces dryer energy use and costs. A few additional notes:

- Units with automatic desiccant regeneration controlled by dew point sensors or by material moisture content are more consistent
- The lower the dew point of the air supplied, the quicker the drying time, but this needs to be balanced against the frequency of regeneration and the energy used for this
- Small spherical desiccant sieves yield faster drying, better reactivation and greater adsorption
- High reactivation temperatures improve reactivation and allow greater adsorption in use.
- Optimize cycle times for the desiccant during drying to avoid overloading the desiccant and thus reducing process efficiency
- Design desiccant drying systems to be “closed loop” to exclude ambient air and obtain the lowest dew point.

---

[10] Courtesy of Dr. Robin Kent, Tangram, Ltd. This excerpt was taken largely from *“Energy efficiency in plastics processing – Practical worksheets for industry – Energy worksheets 1-12,”* Kent, Dr. Robin, Tangram Technology Ltd, 2005 (www.tangram.co.uk)

NEW DRYING TECHNOLOGIES

- **Carousel drying with desiccant**
  This uses a rotating wheel that is impregnated with desiccant crystals. The wheel continuously rotates and passes the desiccant through the adsorption, regeneration and cooling cycles every 4.5 minutes. Control the drying process by adjusting the dryer speed and other variables. The wheel has a low thermal mass that allows the use of lower regeneration temperatures than conventional systems while achieving the necessary overall temperature for regeneration. The wheel produces a lower pressure drop and allows the use of smaller, energy efficient blowers.

- **Low pressure drying**
  Low pressure drying (LPD) uses a vacuum applied to the dryer cabinet to accelerate drying. The vacuum reduces the boiling point of water at 212°F to 133°F and water vapor is driven out of the granules even at low temperatures. LPD reduces drying times by up to 85% reducing energy use by 50% to 80%. It also simplifies the process plant needed for effective drying, as desiccants are eliminated and no longer need to be regenerated and replaced.

  The system is suited to machine-side drying of materials and rapid material changes. The short drying time gives a rapid start-up and the smaller batches of material reduce the clean down and changeover times. LPD also reduces the risk of thermal degradation of the polymer by reducing both the heating cycle and the temperatures used.

- **Infrared rapid drying**
  Infrared drying uses infrared radiation to heat the polymer granules directly. The energy applied to the granules creates internal heating though molecular oscillation. This internal heat drives moisture out of the material into a stream of cool ambient air that removes it from the process. The system uses a drum with an internal spiral feed to transport and agitate the material as it is carried along underneath the infrared heaters. The final moisture content of the polymer is controlled by a combination of the power of the infrared heaters and its residence time in the system.

  Infrared drying is particularly suitable for drying reprocessed PET material because it can combine the processes of recrystallization and drying in a single pass. Drying and recrystallization times for PET can be reduced to less than 10 minutes, with an energy consumption as low as 55 Watt-hours/pound for drying to a final moisture content of less than 0.005%.

APPENDIX A

Checklist for Plastics Energy Best Practices

Best Practice Analyzed? (Date)	Further Review Needed? Yes/No	Best Practice Possible? Yes/No	Area	#	Title	Typical Payback (years)
			Blow	1	Pulse Cooling	1
			Blow	2	Match Blow Former Equipment to Material	Varies
			Blow	3	Implement Proper Die Design	Immediate
			Blow	4	Add Performance-Enhancing Plastic Compounds to Molding Materials	Immediate
			IM	1	Replace Hydraulic Machines with All Electric	5
			IM	2	Pulse Cooling	1
			IM	3	Variable Frequency Drives on Injection Molder	2-3
			IM	4	Variable Frequency Drives on Cooling Water Pumps	2-3
			IM	5	Implement Proper Gate Design	Immediate
			IM	6	Add Performance-Enhancing Plastic Compounds to Molding Materials	Immediate
			Thermo	1	Upgrade Thermoformer Element (includes controls)	2-4
			Thermo	2	Design New Thermoformer with Energy Efficient Element	<1
			Thermo	3	Select Radiant Heater Retrofit to Match Plastic Compound Thermal Properties	1.5
			Thermo	4	Apply Proper Part Design	Immediate
			Thermo	5	Select the Sheet with Proper Physical and Chemical Characteristics	Immediate
			Thermo	6	In-Line Thermoforming	0.5
			Thermo	7	Infrared Scans of Inputs, Processes and Waste Streams	NA
			Extru	1	Post-Heating of the Extrudate	2-3
			Extru	2	Implement Proper Die Design	Immediate
			Extru	3	Add Performance-Enhancing Compounds to Materials	Immediate
			Extru	4	Convert DC Drive to AC Drive	Varies
			Gen	1	Free Cooling	2-4
			Gen	2	Improve Energy Awareness Through Monitoring	<1

APPENDIX B

The following are key energy best practices within common systems in industrial facilities. For more information on these best practices, free technical support to estimate the best practice energy savings for your systems and possible financial incentives call the Focus on Energy - Industrial Program at 800-762-7077.

Best Practices for Common Systems

System	Best Practices	System	Best Practices
Compressed Air			Use VSD instead of bypass control
	Reduce system pressure	**Area Comfort Heating**	
	Repair leaks		Reduce waste heat
	Single vs. two stage		De-stratify heated air in plant
	Variable inlet volume		Control heating to desired temperature
	Variable speed control		Use infrared heating
	Energy efficient motor		Optimize CFM air exhausted
Lighting			Automatic temperature control
	Light meter used to verify levels		Minimize heat to storage areas
	T-8 or pulse start MH lighting are considered	**Comfort Cooling**	
	Occupancy sensors		Install removable insulation
	Lights off during process shutdown		Minimize unnecessary ventilation
	Task lighting is maximized		Minimize moisture released
	Night lighting is turned off		Higher efficiency AC
	LED lamps in exit signs		Optimize room air temperature
Motors		**Dehumidification**	
	Premium efficiency motor vs. repair		Reduce humidity load
	Cogged belts vs. V-belts		Accurately controlling humidity
	Premium efficiency motors specified		Optimize ventilation
Pumps			Desiccant dehumidification
	Trim impeller to meet maximum Load		Minimize reheat energy
	Use VSD instead of throttled control		

Best Practices for Common Systems – continued

Refrigeration		**Fan Systems**	
	Thermosiphon		Reduce excess flow
	Evaporator fan control		Eliminate flow restrictions
	Floating head pressure		Correct poor system effects
	Scheduled maintenance		Optimize efficiency of components
	- Clean filters		Correct leaks in system
	- Low refrigerant charge		Optimize fan output control
	Automatic air purge	**Process Cooling**	
Steam Systems			Use variable frequency drives
	Reduce steam pressure		Float head pressure
	Steam trap maintenance		Use of free cooling - fluid cooler
	Minimize blowdown		Use of free cooling - cooling tower
	Insulate pipes		Match chilled water pumps
	Improve boiler efficiency		Insulate pipes and vessels
	Heat recovery for boiler blowdown		Process to process heat recovery
	Increase condensate return	**Process Heating**	
	Stack economizer		Optimize combustion air fuel ratios
	Recover flash steam		Preheat combustion air
Ventilation			Insulate pipes and vessels
	Direct fired make-up units		Schedule cleaning of heat exchangers
	Better ventilation management		Condensing heat recovery
	De-stratified air		Process to process heat recovery
Wastewater			Ultra filtration for condensation
	Fine bubble diffusers	**Vacuum**	
	Automatic controlled DO sensors/VSDs		Optimize total cost for conveying
	Heat recovery on anaerobic digester		Choose appropriate vacuum pump
	Unneeded aeration basins are shut off		Optimize vacuum pressure
			Eliminate vacuum leaks

APPENDIX C

Plastics Best Practices Team Member Contact Information

Craig Schepp
Energy Advisor
Wisconsin Focus on Energy
SAIC
5609 Medical Circle, Suite 201
Madison, WI 53719
608-277-2948
scheppc@saic.com

Dr. Majid Tabrizi
Center for Plastics Processing Technology
University of Wisconsin – Platteville
Platteville, WI 53818
608-342-1115
tabrizi@uwplatt.edu

Tom Tucker, P.E.
Envise LLC
203 S. Paterson, Suite 200
Madison, WI 53703
608-663-3754
ttucker@envise.net

John Nicol, P.E.
Industrial Program Manager
Wisconsin Focus on Energy
SAIC
5609 Medical Circle, Suite 201
Madison, WI 53719
608-277-2941
john.l.nicol@saic.com

Brent English
CleanTech Partners, Inc.
8309 Greenway Blvd., Suite 220
Middleton, WI 53562
608-203-0113
benglish@cttinc.org

Dr. Robin Kent
Tangram Technology Ltd.
PO Box 24
Hitchin
Herts. SG5 2FP
United Kingdom
+44 8700 278379
rkent@tangram.co.uk

Dean Laube
Energy Advisor
Wisconsin Focus on Energy
Franklin Energy Services
Eau Claire, WI 54701
715-839-0010
deanlaube@franklinenergy.com

APPENDIX D

ADDITIONAL RESOURCES FOR THE PLASTICS INDUSTRY

WISCONSIN FOCUS ON ENERGY: www.focusonenergy.com - offers financial incentives to eligible customers for installing qualifying energy efficiency measures. These measures include energy efficient lighting and HVAC equipment, and "custom" projects such as motor and compressed air system upgrades, process improvements and especially implementing the best practices that this guidebook features. Incentives are also available for maintaining equipment and studying the feasibility of a proposed energy efficiency project. Custom Incentive Partner Guidelines are provided below:

- You must work with a Focus on Energy advisor to obtain approval for custom incentives. If you do not currently have an advisor, please call (800) 762-7077.
- Incentives are available for new projects, not those that have been previously installed. Applications must be submitted before commencement of the project. See the Program Rules and Qualifications at www.focusonenergy.com for more information.
- All custom project incentives are calculated based on first-year energy savings.
- Projects with less than a two year payback are not eligible for custom incentives.
- A $20,000 per application limit has been imposed on lighting-only projects

A comprehensive bonus incentive of an additional 30% may be available for partners who implement multiple projects that increase overall facility energy efficiency.

CENTER FOR PLASTIC PROCESSING TECHNOLOGY – University of Wisconsin-Platteville: http://www.uwplatt.edu/cfppt/ The Center for Plastics Processing Technology at UW-Platteville is dedicated to assisting the existing plastics industry through education and technical services. It is further commited to attracting new plastics-related enterprises to the Tri-State Region of Wisconsin, Illinois and Iowa.

Confidential services are provided at little or no cost by UW-Platteville faculty members and senior-level students in the Department of Industrial Studies. All other university resources are also available to companies and individuals seeking assistance through the program in plastics technology.

In a fast-paced, competitive world, well-trained workers are essential for business growth. The Center for Plastics Processing Technology offers unique resources to help train employees and lead your plastics firm to success. The Center for Plastics Processing Technology is an educational partnership between industry and the university, using plastics processing equipment that was designed and provided by leading manufacturers.

The Center, a laboratory worth more than $1 million, is one of the best-equipped facilities in the Upper Midwest. From plant layout to prototype production to testing new materials, the Center will help meet your needs. Take advantage of these valuable services.

SOCIETY FOR PLASTICS ENGINEERING: http://www.4spe.org
The objective of the Society is " ...to promote the scientific and engineering knowledge relating to plastics."

Every day the Society of Plastics Engineers (SPE) helps people and companies in the plastics industry succeed. How? By spreading knowledge , strengthening skills and promoting plastics. SPE is the only place where people from all parts of the industry can come together around important issues and technologies. SPE's contribution to the plastics industry for over 60 years has made a significant difference to the technologies and innovations the industry enjoys today. In the process, we've developed a 20,000-member network of leading engineers, scientists and other plastics professionals, including technicians, salespeople, marketers, retailers and representatives from tertiary industries.

Today, the industry is more interdependent than ever, and professional networks have taken on global dimensions. Such networks are almost impossible to develop and maintain in our fast-paced industry. Participation in SPE is a key success factor for those who want to thrive in today's business environment.

AMERICAN PLASTICS COUNCIL: http://www.americanplasticscouncil.org The American Plastics Council (APC) is a major trade association for the United States plastics industry. APC advocates unlimited opportunities for plastics and promotes their economic, environmental and societal benefits. To accomplish our mission we demonstrate the benefits of plastic products and the contributions of the plastics industry to the society it serves. We also demonstrate that plastics are an efficient use of natural resources and that plastics and the industry are part of the solution to the public's environmental performance expectations. Our members are among the nation's largest manufacturers of plastics.

The APC communicates with a range of public audiences and officials active on environmental and health issues. An important audience is always teachers -- helping them and their students achieve necessary local and national educational standards. APC helps teachers develop hands-on activities that take complex subjects like polymer chemistry and translate them into fun, exciting activities that all kids can enjoy and retain.

APC continues to develop rigorously researched industry data and solutions addressing plastics and the environment. For instance, we have offered substantial support to the research and development of recovery and recycling technologies for both durable goods (e.g., automobiles and business equipment) as well as packaging. The information learned from these programs is transferred to manufacturers, recyclers, communities and others through our outreach programs. These programs, in turn, help to improve the efficiency and the cost effectiveness of recycling programs and maximize plastics recycling that is economically and environmentally responsible and sustainable.

CLEANTECH PARTNERS, INC. (formerly CENTER FOR TECHNOLOGY TRANSFER, INC.): www.cleantechpartners.org - CleanTech Partners helps companies overcome barriers that restrict the commercialization of energy efficient technologies in Wisconsin.

CleanTech Partners provides capital in the form of loans or equity to companies not typically served by traditional financial resources. This capital, coupled with technical, business and financial expertise can help bridge the gaps preventing the adoption and commercialization of new technology.

CleanTech Partners' technology investment funds are aimed at companies with technologies specific to the forest products (paper), metal casting, food processing, printing and plastics industries. CTT will also consider investment in other areas that will have a significant impact on energy use in Wisconsin. Businesses that have technology ready for commercialization in the near term, as well as business with commercialized technology that is not currently offered in Wisconsin, are especially encouraged to contact CleanTech Partners.

US – DEPARTMENT OF ENERGY – ENERGY EFFICIENCY AND RENEWABLE ENERGY (EERE) - EERE offers valuable tools and publications to help industrial companies improve productivity and energy efficiency. These resources are listed below, you can learn more by visiting the Best Practices website at www.eere.energy.gov/industry/bestpractices or by calling the EERE Information Center at 877-337-3463.

Publications : *http://eereweb.ee.doe.gov/industry/bestpractices/publications.asp* Whether you're looking for information on how to recover waste heat from your steam system or wondering about the market potential of efficient motors, the Best Practices library has the publication for you:

- DOE G 414.1-2, Quality Assurance Management System Guide – systems for conducting best practices. http://www.directives.doe.gov/pdfs/doe/doetext/neword/414/g4141-2.pdf
- Corporate Energy Management Case Studies - These case studies can help decision makers examine the bottom line benefits that result from successful applications of energy efficient practices and technologies. *www.ase.org/section/topic/industry/corporate/cemcases/*
- Technical Publications – Materials on buying, maintaining, and assessing industrial systems and components; overviews of the energy-efficient motor and compressed air markets; and specific information on Best Practices tools.
    - Technical Fact Sheets and Handbooks provide "how-to" technical detail on increasing system efficiencies.
    - Tip Sheets provide quick advice on how to keep your systems running at their maximum efficiency.
    - Best Practices Resources provide information on the tools available from the Best Practices portfolio.
    - Market Assessments provide a look at the market for energy efficient industrial systems and components, and offer strategies to influence that market.
    - Sourcebooks provide information on activities, resources, applications, standards and guidelines for increasing industrial energy efficiency.
    - Repair Documents for motors.
- ITP E-Bulletin – Monthly online connection to news and resources from ITP—including announcements about new tools and resources.
- Training Materials – A range of materials—notebooks, CDs, viewgraphs—designed to spread the word about the benefits of industrial energy efficiency and how to achieve it.

Training: Best Practices offers system-wide and component-specific training programs to help you run your plant more efficiently. The training is offered throughout the year and around the country.

- End-User Training for compressed air, motor, process heating, pump and steam systems.

- Specialist Qualification Training offers additional training in the use of specific assessment and analysis software tools developed by DOE.
-

Plant Assessments: Plant assessment assistance is available to help you and your customers identify opportunities to improve the bottom line by reducing energy use and enhancing productivity.

- Plant-Wide Assessments investigate overall energy use in industrial facilities and highlight opportunities for best energy management practices. Approximately once per year, plants are selected through a competitive solicitation process and agree to a minimum 50% cost-share for implementing the assessment.
- Industrial Assessment Centers (IAC) are aimed at small- to medium-sized manufacturers and provide a comprehensive industrial assessment at no cost. Engineering faculty and students conduct energy audits or industrial assessments to identify opportunities to improve productivity, reduce waste and save energy.

Software: ITP's comprehensive suite of software tools can help your organization identify energy savings opportunities. Visit the Web site to learn more and download these tools, free of charge, to improve industrial compressed air, motor, fan , pump, process heating and steam systems:

- ASDMaster evaluates adjustable speed drives and their application
- AirMaster+ assesses compressed air systems
- MotorMaster+ and MotorMaster+ International assists in selecting and managing energy-efficient motors
- Process Heating Assessment and Survey Tool (PHAST) assesses process heating systems
- Pumping System Assessment Tool (PSAT) assesses the efficiency of pumping systems
- NOx and Energy Assessment Tool (NxEAT) assesses and analyzes NOx emissions and applications of energy-efficient improvements
- Steam System Scoping Tool (SSST) profiles and grades steam system operations and management
- Steam System Assessment Tool (SSAT) assesses steam systems
- 3E Plus determines whether boiler systems can be optimized through the insulation of steam lines

Databases: ITP's on-line databases can help you make contact with best practices service providers, review results of plant assessments, and find a variety of additional tools.

- Allied Partners Database contains information on private companies, organizations, and government agencies that provide equipment, assistance, or services to manufacturers.
- The Industrial Assessment Center (IAC) Database contains the actual results of approximately 7,000 assessments conducted by the IACs. The database includes details including fuel type, base plant energy consumption, and recommended energy efficiency improvements, in addition to projected energy savings, cost savings, implementation cost, and simple payback.
- The National Inventory of Manufacturing Assistance Programs (NIMAP) database provides an extensive listing of organizations that offer assistance to industrial firms. NIMAP links industrial customers to potential resources to help them address energy management responsibilities, including operations, maintenance, and training issues, as well as equipment sourcing and financing.

Energy Consumption by Manufacturer-MECS data for 1998. See
http://www.eia.doe.gov/emeu/mecs98/datatables/contents.html

TANGRAM TECHNOLOGIES Ltd. http://www.tangram.co.uk/ Consulting Engineers for Plastics Products: Tangram Technology, a member of the Plastics Consultancy Network, provides high quality training, technical writing, change management, product design and field services to all areas of the plastics products and window industries. Services are designed for plastics processors, window systems suppliers, specifiers and large contractors, hardware manufacturers, fabricators and other companies involved in the polymer processing or window industries.

PSIGATE – PHYSICAL SCIENCES INFORMATION GATEWAY
PSIgate is a free service that offers access to high quality Web resources in the physical sciences; there are currently 13863 resources in astronomy, chemistry, earth sciences, materials sciences, physics, and general science. For publications on the topic of plastics processing energy efficiency, including those of Dr. Robin Kent, go to: www.psigate.ac.uk/roads/cgi-bin/search_webcatalogue2.pl?limit=0&term1=carbon*%20+management

FORWARD WISCONSIN. See http://www.forwardwisconsin.com
Forward Wisconsin's role in the economic development arena is to help businesses establish profitable Wisconsin operations. We provide state cost comparisons, Wisconsin financial information and a variety of other relocation consulting services to prospective expanding businesses. Access the new Wisconsin Plastics Business Directory available online in PDF format.

PUBLICATIONS AND REFERENCES

"Practical Energy Management, Tools for Creating and Implementing an Energy Management Program," Focus on Energy," 2003.

"Reduced Energy Consumption in Plastics Engineering - 2005 European Benchmarking Survey of Energy Consumption and Adoption of Best Practice," RECIPE, September 30, 2005

"Energy efficiency in plastics processing – Practical worksheets for industry – Energy worksheets 1-12," Kent, Dr. Robin, Tangram Technology Ltd, 2005 (www.tangram.co.uk)

"Energy in plastics processing – a practical guide - Good Practice Guide 292", Best Practice Programme, ETSU and British Plastics Federation (Kent, Robin and Cheater, Gerald),1999.

"Good Practice Guide 316 – Undertaking an industrial energy survey," NIFES Consulting Group with Creative Climate Ltd for Energy Efficiency Best Practice Programme, 2002.

APPENDIX E

ACKNOWLEDGEMENTS

The authors would like to acknowledge the generous contributions of the following individuals and organizations for their assistance with review, comments and addition to content.

Genise Smith-Watkins
Midwest Regional Director
American Chemistry Council
400 Robert Street North
Suite 1580
Saint Paul, MN 55101

D'Lane Wisner
Lead Staff – APC Buildings & Construction Team
3407 Antony Drive
Broadview Heights, OH 44147

Lance Hampel
CEO
Hampel Corporation
W194N11551
McCormick Drive
Germantown, WI 53022

Lisa Esser
Manufacturing Engineer
Miniature Precision Components
63095 Vineyard Road
Prairie du Chien, WI 53821

Larry Floyd
President
Plastics Mold Concepts
111 Murphy Drive
Eagle, WI 53119

Bob Whitish
Plant Manager
Plastic Ingenuity
1017 Park St.
Mazomanie, WI 53560

Dr. Robin Kent
Tangram Technology Ltd.
PO Box 24
Hitchin
Herts. SG5 2FP
United Kingdom

Bruce Williams
Corporate Energy Manager
Bemis Corporation
2621 W. Everett St.
Appleton, WI 54914

Terry Stephens
SBU Team Leader
Midland Plastics, Inc
5405 S. Wesrridge Court
New Berlin, WI 53151

Tom Hartmann
Manager of Manufacturing Engineering
MRPC also SPE X President
13161 W. Glendale, Ave.
P.O. Box 246
Butler, WI 53007-0246

Greg Knudson
Plant Engineer
Northern Engraving (West Salem)
600 Brickl Road
West Salem, WI 54669

Mike Thomas
SPE Milwaukee-Board
2845 Cambridge Circle
Brookfield, WI 53045-3230