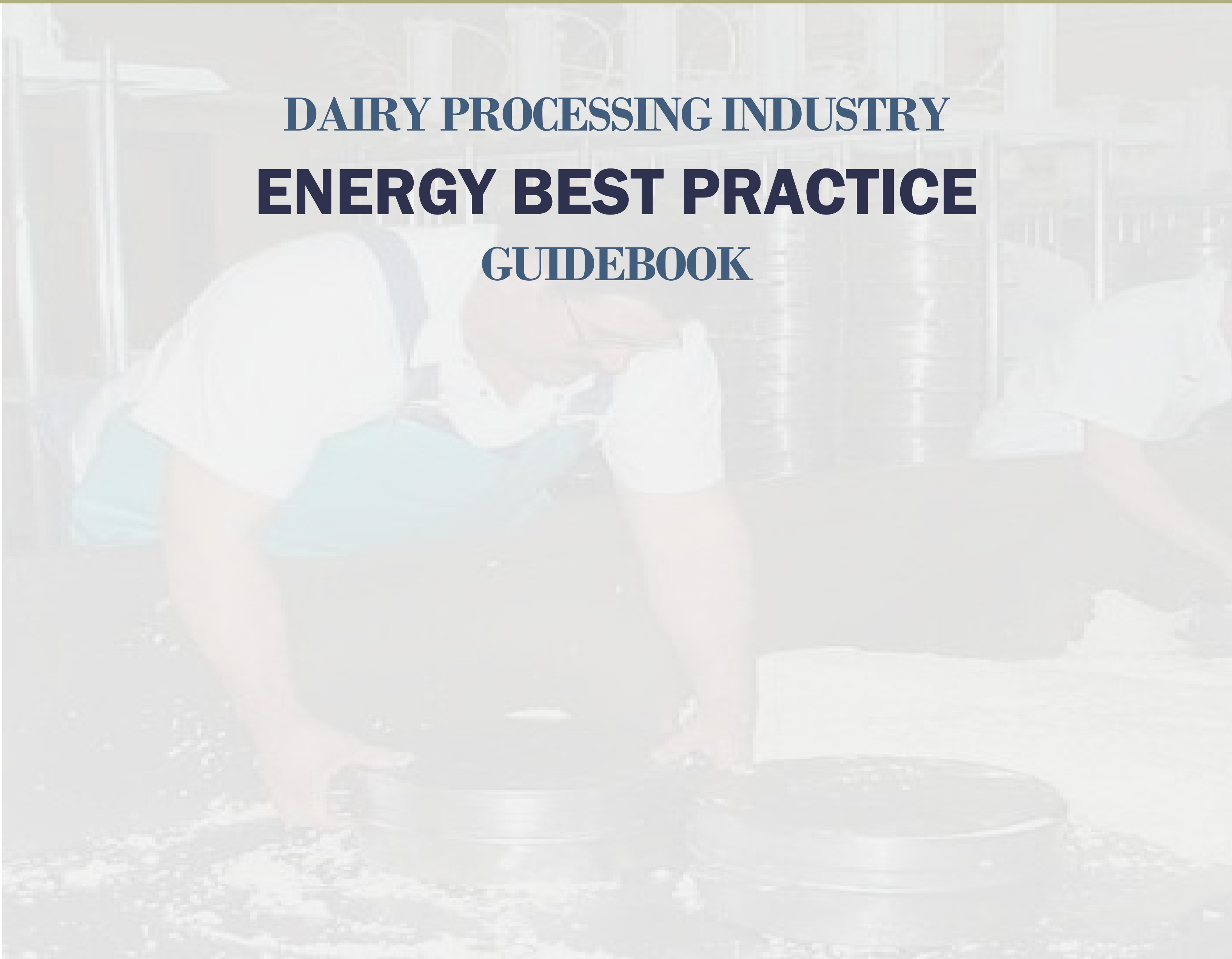
DAIRY PROCESSING INDUSTRY

ENERGY BEST PRACTICE

GUIDEBOOK



focus on energy[SM]

The power is within you.

Dairy Processing
Energy Best Practice Guidebook

Provided By:

focus on energy[sm]
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
EnVise
GDS Associates
CleanTech Partners, Inc.
Industrial Refrigeration Center
University of Wisconsin-Biological Systems Engineering

July, 2006

TABLE OF CONTENTS

FORWARD

Are You A World Class Energy Consumer?

World class energy users have:

1. Benchmarked energy consumption in their dairy processing facility
2. Defined quantifiable, affordable energy reduction goals
3. Established a multi-year plan to meet their energy reduction goals
4. Assigned a cross-functional team to implement the plan
5. Reporting, feedback and renewal process
6. Obtained firm commitments from their facility manager for improvements in energy efficiency and demand reduction

If your dairy processing facility lacks any of these essential ingredients, this best practice guidebook will help you get there.

What Others are Saying about the Guidebook:

John Umhoefer, Executive Director, Wisconsin Cheesemakers Association

> "***Rising energy prices continue to be a concern for our industry. This guidebook provides several ideas that will help reduce energy costs for our members."***

Nick George, Executive Director, Midwest Food Processors Association

> ***"The Best Practices Guidebook is a great tool to help energy practitioners make an immediate impact on conservation and efficiency. That is critical to our industry's competitiveness in an era of rapidly increasing energy prices.***"

Jim Cisler, GROW Wisconsin Dairy Lead, Department of Agriculture, Trade and Consumer Protection

> "***With today's rapidly rising energy costs, this is great information every dairy processing facility manager will want to put to use to improve the bottom line."***

Executive Summary

The objective of this Dairy Processing Energy Best Practice Guidebook is to provide resources and methods to reduce energy use and energy related costs in dairy processing facilities. Using this guidebook, dairy processing facility managers will learn how to manage energy in their facility and uncover opportunities to significantly reduce facility energy consumption.

Contents include:

- Guidelines and tools for energy management best practices
- Average energy use for typical dairy processing facilities
- Description of over 20 best practices for process energy use and other best practices for common system energy use
- Best practice funding and financing opportunities
- References for further opportunities in dairy processing energy efficiency and energy demand reduction

The intent of the **Guidebook** binder format is to provide a document that can be updated continually with new Best Practices and Case Studies provided by the Focus on Energy program (and others) with direct input from dairy processing industrial leaders. In addition to this guidebook, the Focus on Energy Program can provide technical assistance and possible financial incentives to support the implementation of energy efficiency measures you may want to pursue. We encourage you or your staff to give us a call at
800-762-7077 to find out how we may be able to help you reach your energy cost reduction goals.

INTRODUCTION

The past two decades have brought significant change to the dairy industry in Wisconsin. Competition from western states, volatile milk prices, and changing consumer tastes have significantly altered the playing field. Competition has evolved from simply selling products to the more complex challenge of promoting the dairy processing facility from both an internal and external context. Facilities are under constant scrutiny to be productive, innovative, and cost competitive.

The first and most obvious change in dairy processing facilities is staff downsizing to reduce costs. Dairy processing facilities are now operating with minimal technical and support staff. One negative aspect of this change is a focus on today's issues with little time for the future. A dairy processing facility cannot adopt a technology if it is unaware of its existence. This phenomenon is furthered by the lack of capital and staff to exploit or implement identified technology. One response to this challenge is to learn how to cost effectively use outside resources.

A second, more subtle, but equally significant factor influencing dairy processing facilities is managing and reducing energy costs. Although energy is one of the top three costs of doing business, improving labor productivity or saving money on raw material is viewed as more immediate and measurable. Energy costs, on the other hand, are not easily influenced and many dairy processing facilities still view them as a semi-fixed expense. One response to this challenge is to have a long-term energy reduction plan that is supported at the highest levels of the organization.

A third challenge is access to energy conservation information. Today's decision makers typically include corporate executives as well as resident facility managers. The array of assets controlled under a single corporate umbrella is much larger today than in the past. Good technical ideas are often tempered on factors well beyond the confines of a single dairy processing facility. The fit must first satisfy the overall corporate objective before implementation within the organization. Innovation is not bound by geography so an idea proposed for one facility may well be implemented elsewhere, and yet ignored at the originating location. The most effective response is to have dairy processing facility manager ownership of the energy reduction plan so that it can be advocated at every opportunity.

Development of the Guidebook

Funding for this best practice guidebook was provided by Focus on Energy. The following Focus on Energy Dairy Processing team members contributed to the development of this guidebook:

- **John Nicol, P.E.,** Sector Manager – Focus on Energy's Industrial Business Program – SAIC
- **Rich Hackner, P.E.,** Sector Manager – Focus on Energy Agriculture & Rural Business program – GDS Associates
- **Tom Tucker, P.E.,** Senior Consultant – EnVise LLC
- **Craig Schepp,** Focus on Energy Advisor and Program Outreach Manager – SAIC
- **Douglas Reindl, P.E.,** Professor in the College of Engineering at the University of Wisconsin-Madison. Director of the Industrial Refrigeration Consortium.
- **Doug Reineman,** UW-Madison Professor in the College of Agriculture and Life Sciences
- **Preston Schutt,** Director of Food and Bio-based Industry – CleanTech Partners, Inc.

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 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 the demands of 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. Many plants have realized additional benefits of energy management programs including: increased plant production capability, improved safety and increased yields.

Energy efficiency is a good investment. Many energy efficiency projects provide a high return on investment (ROI) – as much as 100% or more – and are low risk. When compared to other investment opportunities, these projects can be very attractive. Typically, you can achieve 10% to 15% 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. Focus on Energy has developed a set of tools called **Practical Energy Management©** 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: Establish the Baseline Energy Use: Compile your monthly utility bills to develop an overall energy profile of your facility. Put energy in the context of overall organizational operations by comparing it to more widely tracked measures such as profit, sales or labor costs. Begin by tracking your monthly energy bills along with production (see example in **Figure 3.1**). Then develop your facility's **Energy Profile Summary**, showing changes in consumption and in your **Key Performance Indicators (KPI)**, by year (**Figure 3.2**).

Next set your present baseline and target for your energy **KPI,** e.g., a 5% reduction in energy by the end of the year. Then track and graph your energy KPI for each month (see example in **Figure 3.3**). 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 usage 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 with existing data. Record the factory output in lb of product processed for a number of months or weeks along with the energy usage for the same period. A plot of energy usage (kWh or therms) versus production level can then be made. **Figure 3.4** shows 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 usage when no production is taking place.

Step 2: Estimate Energy Use for Major Systems: Determine the energy used by major equipment and energy-consuming systems. This can point the way to your largest energy uses and the best places to focus your attention (see example in **Figure 3.5**). A further task would be to develop process flow diagrams that include the flow rates and associated temperatures for key processes (see **Figure 3.6**). You may also want to compare your processing energy use to the average values listed in **Table 1**. This may be a task completed over a longer period.

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 dairy industry.

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

Step 5: Prioritize Projects: 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 ROI, level of capital cost or ease of installation to help you or prioritize all the energy savings opportunities identified. Select the highest scoring projects for implementation to achieve your energy savings goals within time and budget constraints. Operational risk should also be considered during the process of prioritizing projects. Projects that have the greatest ROI with the least operational risk should receive the highest priority for implementation.

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, and undertaking specific tasks needed to implement the project.

Figures 3.1 through **3.5** on the following pages are examples of the tools included in the **Practical Energy Management**© approach that can be obtained from Focus on Energy for free to eligible Wisconsin industries.

Figure 3.1 – Tracking Electric Use

Big Cheese International

Electric Rate $0.06

Month	KWh/ton of Cheese	Consumption (kWh)	Prod Units Tons Cheese	Billed Demand (kW)	Total Electric Cost
Jan	336	724,416	2156	1086	$43,465
Feb	328	693,064	2113	1086	$41,584
Mar	331	707,678	2138	1086	$42,461
Apr	321	663,507	2067	1086	$39,810
May	312	641,160	2055	1086	$38,470
Jun	317	669,187	2111	1052	$40,151
Jul	316	656,964	2079	1051	$39,418
Aug	312	655,512	2101	1037	$39,331
Sep	309	648,282	2098	1046	$38,897
Oct	311	638,483	2053	1046	$38,309
Nov	310	620,930	2003	1046	$37,256
Dec	307	621,982	2026	1046	$37,319
AVG	**318**			**1063**	
5% GOAL	**313**				**-$23,823**
TOTAL		**7,941,165**	**25,000**		**$476,470**

Figure 3.2 - Facility Energy Profile - Summary

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

Big Cheese International

Electricity	2005	2004	2003	% Change 2004 to 2005
Consumption (kWh)	7,941,165	8,274,694	8,291,243	-4.03%
Electrical Cost ($)	$714,705	$744,722	$746,212	-4.03%
$ per kWh	$0.090	$0.090	$0.090	0.00%
Key Performance Indicators				
Tons of Cheese	25,000	25,233	25,234	-0.92%
KWh per Ton of Cheese	318	328	329	-3.13%
Electric $ per Ton of Cheese	$28.59	$29.51	$29.57	-3.13%
Business Indicators				
Operating Costs	$24,000,000	$23,400,000	$23,600,000	
Electricity as % Oper. Costs	2.98%	3.18%	3.16%	
Annual Profits	$2,640,000	$2,340,000	$2,360,000	
Electricity as % of Profits	27.07%	31.83%	31.62%	
% increase in profits with 5% reduced electricity costs	1.35%	1.59%	1.58%	

Figure 3.3

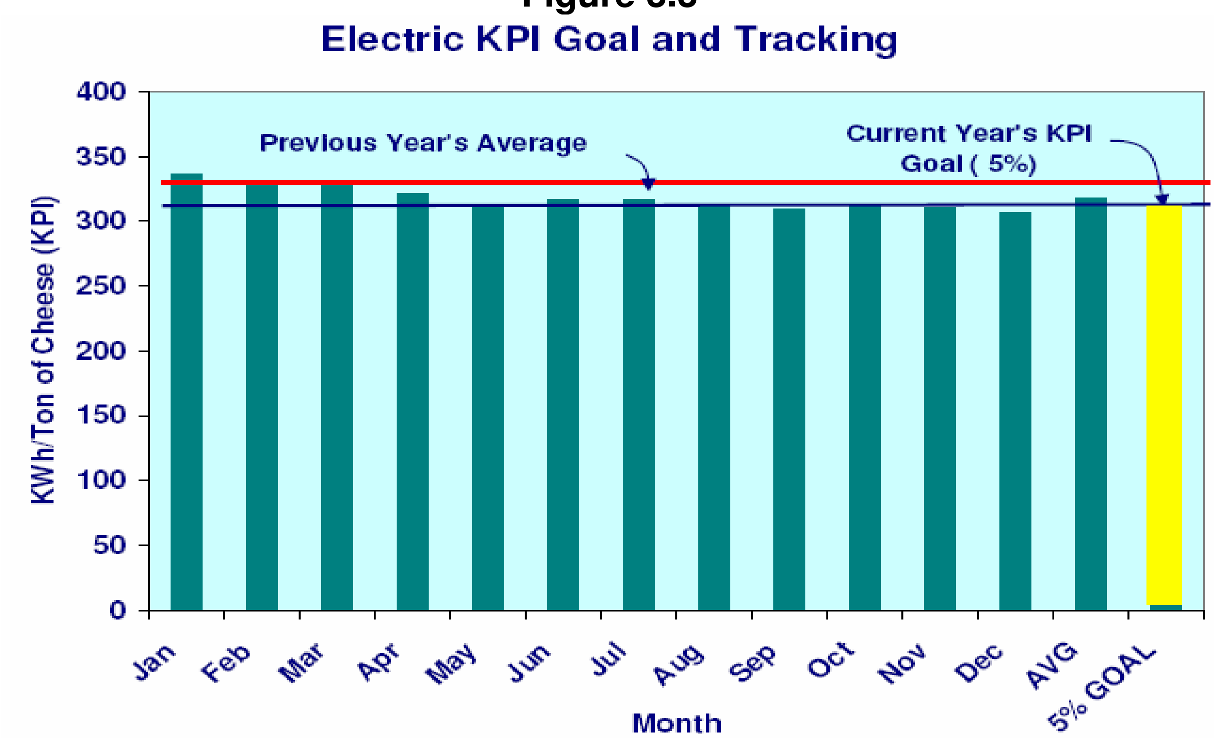


Figure 3.4

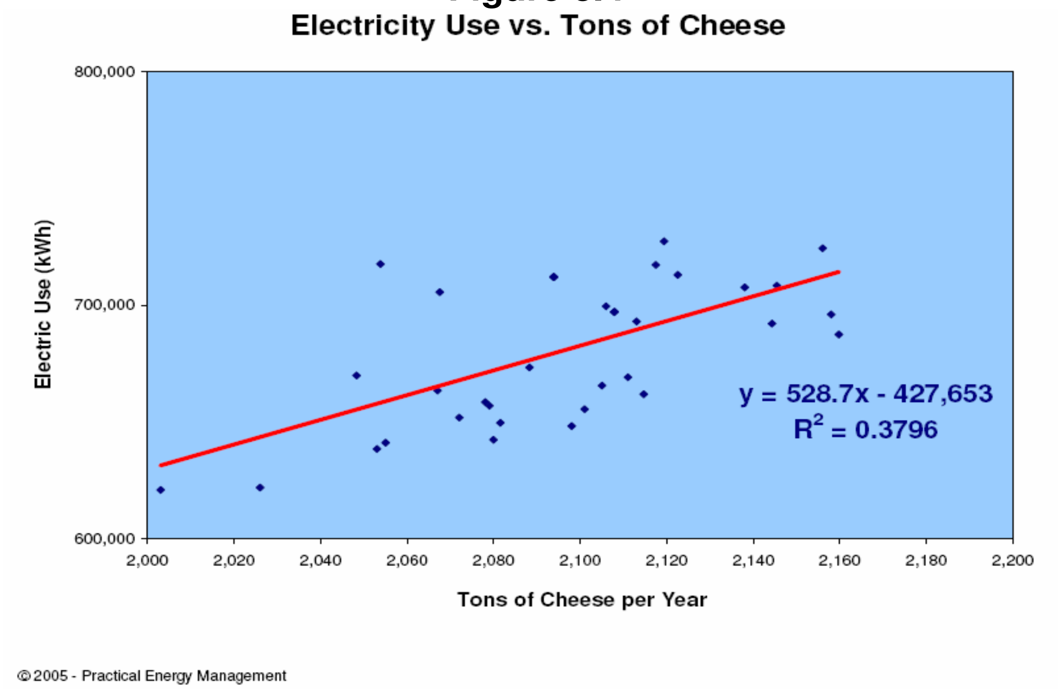


Figure 3.5

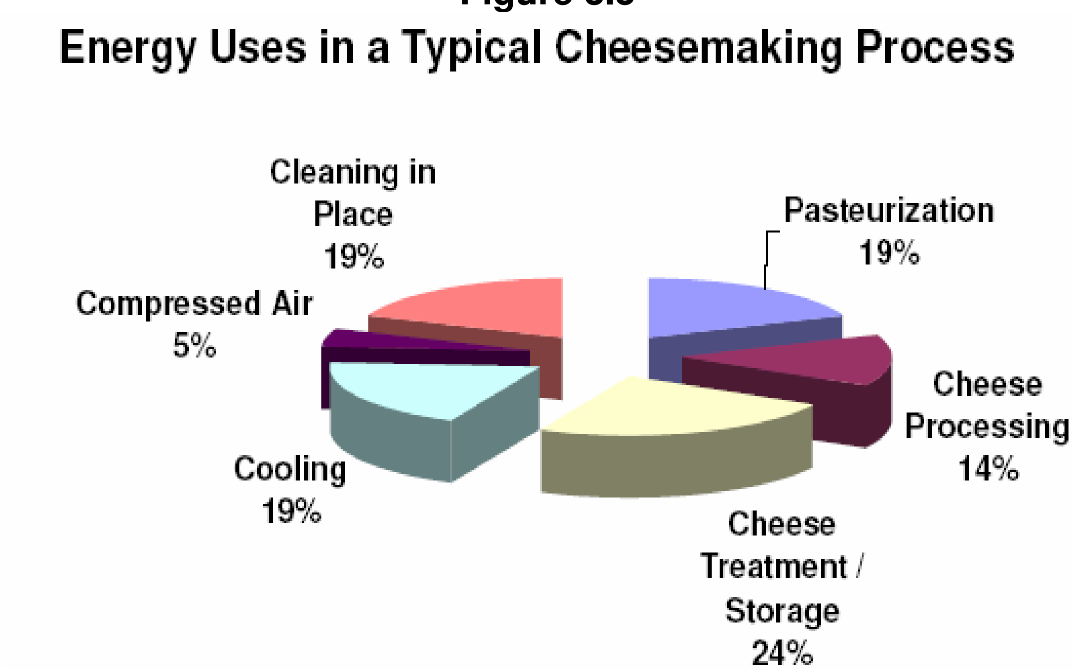


Figure 3.6 Simplified Generic Dairy Processing Sequences

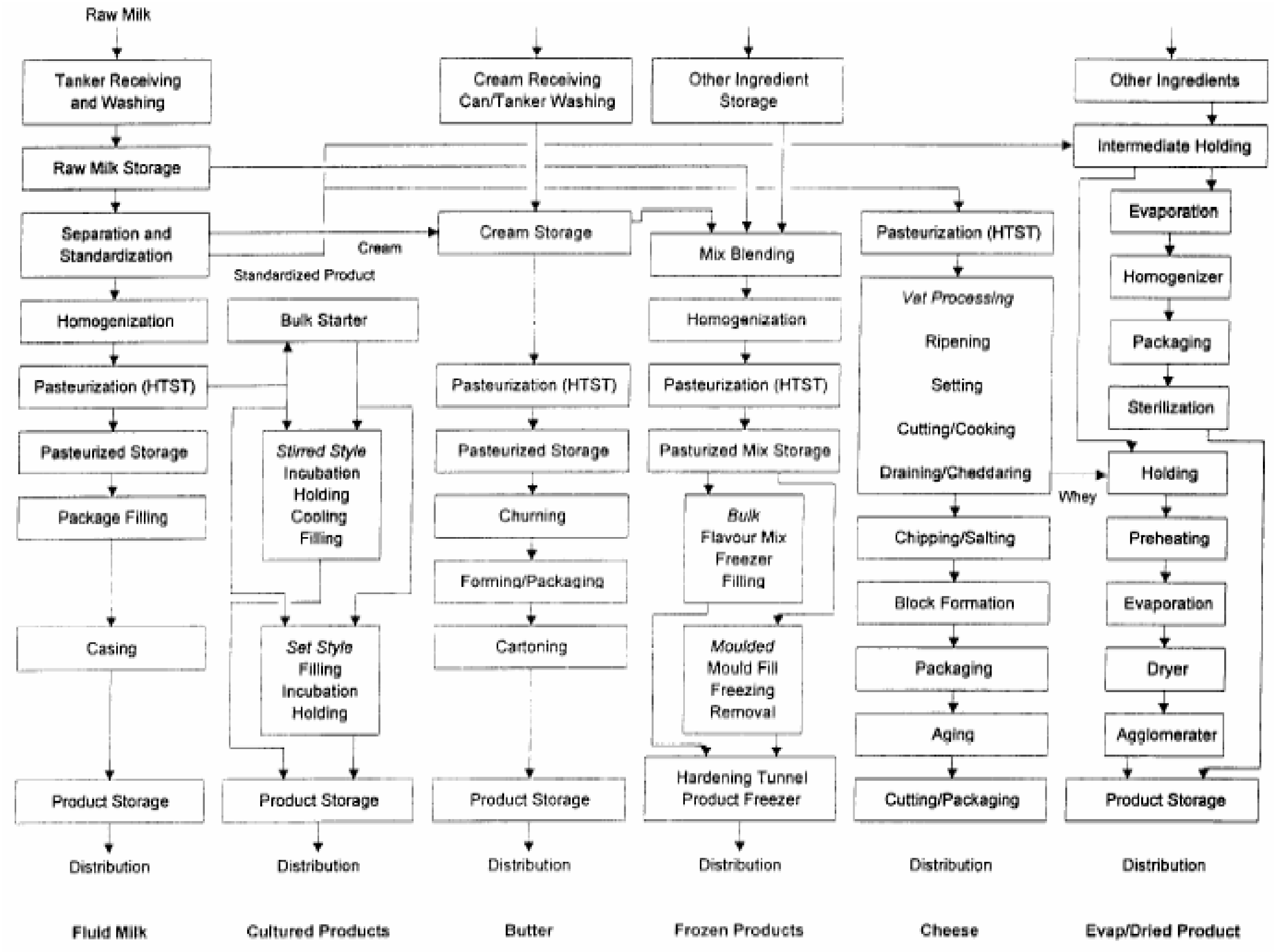


Table 1: Average Energy Use per Ton of Product

Product	Process	Energy Consumption%	MMBtu/ton of product[1]
Butter	Cooling	66%	1.25
	Compressed Air	8%	0.15
	Cleaning in Place	26%	0.49
	Total	**100%**	**1.90**
Cheese	Reception/thermization	19%	0.70
	Cheese Processing	14%	0.52
	Cheese Treatment/Storage	24%	0.89
	Cooling	19%	0.70
	Compressed Air	5%	0.19
	Cleaning in Place	19%	0.70
	Total	**100%**	**3.71**
Fluid Milk	Reception/thermization	2%	0.02
	Storage	7%	0.07
	Centrifugation/homgenization/pasteurization	38%	0.36
	Packing	9%	0.09
	Cooling	19%	0.18
	Compressed Air	0.50%	0.0
	Cleaning in Place	9.50%	0.09
	Process Water	6%	0.06
	Space Conditioning	9%	0.09
	Total	**100%**	**0.95**
Milk Powder	Thermization/pasteurization/centrifugation	2.5%	0.24
	Thermal concentration/evaporation	45%	4.30
	Drying	51%	4.88
	Packing	1.5%	0.14
	Total	**100%**	**9.56**

Source: Adapted from Energy Use and Energy Efficiency in the European Dairy Industry, Ramirez, et. al. 2004

To compare your facility's baseline energy use to the values in **Table 1**:

1: Convert annual kWh to $MMBtu_{ELECTRIC}$:

$$[kWh \times 3413\ Btu/kWh] / 1x10^6\ Btu/MMBtu = MMBtu_{ELECTRIC}$$

2: Determine total baseline energy,

$$MMBtu_{GAS} + MMBtu_{ELECTRIC} = MMBtu_{TOTAL}$$

3: Divide the results from # 2 by your annual primary production (in tons).

[1] MMBtu is a combination of gas use and electric use. Electric use is converted to MMBtu using the following formula: kWh times 3413 Btu/kWh divided by 1E06 Btu/MMBtu.

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.

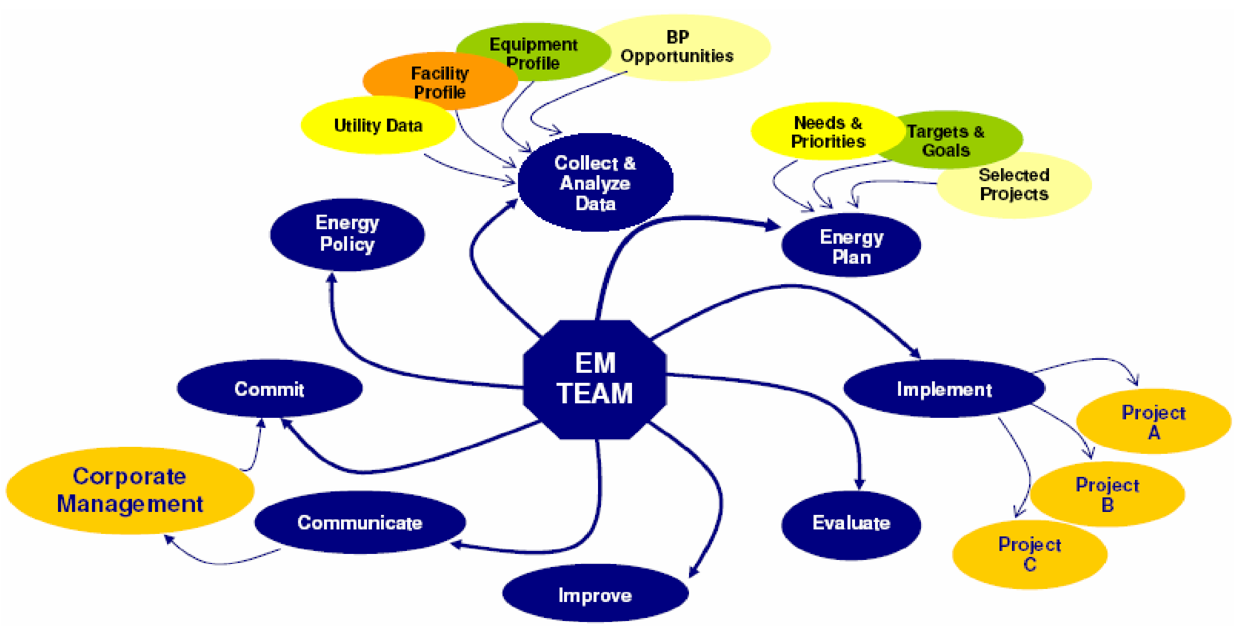
Step 2: Form an Energy Team: An energy team formed from a cross the company should include personnel from maintenance, engineering, production, management and financing. This team should meet periodically as needed to review progress on the energy management plan and set new direction.

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 called "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 3.7): 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 3.7 – Continual Improvement Cycle



TECHNICAL BEST PRACTICES

The information presented in the previous section: Understanding your plant energy use, processes and benchmarking current practices, are the first steps to improve plant energy performance. To facilitate improving the efficiency of dairy plant operations, Focus on Energy has cultivated proven best practices that reduce both thermal and electrical energy consumption associated with a wide range of dairy process operations. The dairy processing industry best practices included in this document were compiled by the development team from literature reviews, personal experience and interviews with both dairy processing facility and vendor personnel. In most cases, resources for additional information are provided. Review the best practices to see if there may be similar opportunities within your plant. Contact Focus on Energy if you need assistance or further information on reducing your plant's energy usage at 800-762-7077.

Table 2 on the following page is a list of all the best practices included in this guidebook. **Appendix A** contains a **checklist** for these best practices that could be used to ensure proper consideration. The best practices in this section primarily relate to process energy use typically unique to the dairy processing industry. Additional best practices for common support systems that are found in most industrial facilities, such as lighting and compressed air systems, are located in **Appendix B**. These should also be reviewed for energy cost reduction opportunities for these common systems.

Best Practices Unit Definitions and Baseline
English (US) units will be used unless otherwise stated. The major energy units used are Millions of Btu's (MMBtu) and kilowatt-hours (kWh). Costs were arbitrarily selected as:

- $5.00 per MMBtu
- $0.045 per kWh ($275 per hp-year)

Table 2
Dairy Processing Energy Best Practices

REFRIGERATION	
1	Reset Floating Head Pressure Control
2	Raise Suction Pressure
3	Screw Compressor Oil Cooling Conversion: Liquid Injection to
4	Dedicated Condenser for Oil Cooling
5	Screw Compressor Sequencing
6	Manage Liquid Make-up
7	Two-stage Compression
8	Free-cooling
9	Variable Frequency Drives on Evaporator Fans
10	Variable Frequency Drives on Screw Compressors
11	Variable Frequency Drives on Condenser Fans

WHEY DRYING	
1	Mechanical Vapor Recompression Evaporators
2	Spray Dryer Heat Recovery

CONCENTRATION	
1	Reverse Osmosis Concentration

STEAM SYSTEM	
1	Heat Recovery from Continuous Boiler Skimmers
2	Boiler Exhaust Heat Recovery with Condensing Economizer
3	Initiate a Steam Trap Program
4	Reduce Boiler Pressure

PROCESS HEAT	
1	Select Proper Heat Exchanger for Pasteurizer

GENERAL	
1	Metering and Monitoring for Energy Efficiency and Cost Reduction
2	Replace Agitator Motors

Refrigeration 1 – Reset Floating Head Pressure Control

Best Practice	Many refrigeration systems operate with unnecessarily high head pressure. Lowering your system's minimum head pressure set point can result in significant energy savings.
Primary Area/Process	Industrial refrigeration systems.
Productivity Impact	None, as long as product design conditions are met.
Economic Benefit	In the simplest form, this practice involves resetting controls – at no capital cost. Payback is immediate. Equipment or system changes may be required (See ***Limitations***, below).
Energy Savings	Refrigeration system efficiency improvements with this strategy range between 5% and 20%.
Applications & Limitations	There are limits on how much a system's minimum head pressure can be lowered. Many constraints are easily overcome while others involve capital expenditures. Most constraints come from the decreased pressure of high pressure liquid being fed to the low side of the system and include: pressure differential requirements for direct-expansion loads, liquid injection oil cooling for screw compressors, hand-expansion valve settings for liquid make-up to recirculators and flooded evaporators, controlled pressure liquid receiver set points and operation of gas-driven transfer systems. Each of these must be evaluated for a system.
Practical Notes	Typically, industrial ammonia refrigeration systems operate with a minimum-head pressure set-point in the range of 150 to 165 psig. This energy efficiency opportunity involves re-setting the system's lower limit on head pressure yielding reduced overall system energy consumption and improved efficiency. Lowering the minimum-head pressure set-point for a refrigeration system is the single largest energy efficiency opportunity for most plants. The major energy consumer in a refrigeration system, the compressor, will see about 1.3% improved efficiency (lower BHP per ton) for each degree Fahrenheit that the saturated condensing temperature is lowered (e.g., 3 psig for an ammonia system).
Other Benefits	Reduces the compression ratio on compressors for more hours during a year, thereby reducing compressor wear, helping to extend compressor life.
Stage of Acceptance	Many plants have exploited this opportunity by systematically lowering head pressure until a constraint arises. They assess the constraint and eliminate it to allow further reductions in head pressure. The best practice plants using ammonia refrigeration systems run system head pressures below 100 psig during cool weather operation.

Resources

For information on this best practice see: the
IRC Industrial Refrigeration Energy Efficiency Guidebook

A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 2 – Raise Suction Pressure

Best Practice	Raising suction pressure can increase a compressor's efficiency and deliver significant refrigeration system energy savings. As suction pressure rises, compressor capacity increases while required power increases only slightly.
Primary Area/Process	Potentially, applicable to all industrial refrigeration systems.
Productivity Impact	Raising suction pressure lowers compressor HP per ton because the pressure ratio across the compressor is reduced. While improving system efficiency, additional benefits may outweigh the efficiency gains, e.g., during an expansion compressor capacity gains from raising suction pressures that may off-set the need to purchase a new compressor.
Economic Benefit	In the simplest form, raising suction pressure involves resetting controls along with the possible need to remove components such as evaporator pressure regulators. In some cases, electric motors on compressors may need replacement (or imposition of current limits). Work with a refrigeration professional to evaluate whether or not capital improvements are needed.
Energy Savings	As a rule, compressor efficiency increases about 2.5% per each degree Fahrenheit increase in saturated suction temperature. Efficiency gains range up to 10%.
Applications & Limitations	Although the opportunity to raise suction pressure is present in most industrial refrigeration systems, it is particularly available in dairies. Many dairies operate at 25 psig suction pressure, corresponding to a saturation temperature of 11^{o} F. For most dairy operations, this refrigerant temperature is lower than needed for processes. To compensate, they add evaporator pressure regulators to raise the evaporator pressure/temperature. In nearly all cases, suction pressure can be reset upwards with positive impacts.
Practical Notes	Allows compressors to generate greater refrigeration capacity. Some constraints, including verifying compressor motor power capability at the new pressure, oil separator performance, and settings of other pressure regulators at that suction level in the plant, need to be evaluated to insure satisfactory system performance.
Other Benefits	This practice lowers the compression ratio on high-stage and single-stage compressors, reducing compressor wear and helping extend compressor life.
Stage of Acceptance	Raising suction pressure is a proven high-impact approach to increase plant energy efficiency. However, many plants have overlooked this fundamental opportunity.

Resources

For information on this best practice see: the IRC Industrial Refrigeration Energy Efficiency Guidebook

A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 3 – Screw Compressor Oil Cooling Conversion: Liquid Injection to Thermosiphon

Best Practice	Screw compressors for industrial refrigeration systems require oil cooling to maintain satisfactory operation. Many screw compressors use high-pressure liquid refrigerant expanded directly into the compressor to cool the oil. This method is called "liquid injection" or SOC-screw (or side) oil cooling. Best practice refrigeration systems use indirect thermosiphon systems to cool oil instead of liquid injection.
Primary Area/Process	New installations and expansion of existing systems are the best opportunities for thermosiphon oil cooling.
Productivity Impact	By itself, a liquid injection to thermosiphon conversion will provide a very small increase in compressor capacity. A side benefit of this conversion is that it provides more opportunity to reduce a system's minimum-head pressure further.
Economic Benefit	The thermosiphon conversion for one Wisconsin industrial refrigeration system with about 5,000 total HP resulted in estimated energy savings of 1,150,000 kWh and energy cost savings of $53,000 per year. This translates to an approximate 9% reduction in compressor and condenser energy use. The simple payback was estimated at four years, without incentives. The facility's electric utility provided a rebate that reduced the payback by nearly one year. The conversion also freed up nearly 90 tons of high-stage load during peak production.
Energy Savings	The efficiency gain from this conversion will vary depending on the compressor design and package. Generally, as the operating compressor suction pressure decreases, the efficiency benefit from this conversion increases. For suction pressures that correspond to temperatures in the region of 0°F [-18°C], the efficiency penalty for liquid injection oil cooling is on the order of 5% (see table on next page). At suction pressure of 10.4-psig (-40°F/-40°C), the liquid injection oil cooling efficiency penalty increases to over 15%.
Applications & Limitations	Proper refrigerant piping practices are necessary for thermosiphon system operation. An extension of this oil cooling method involves the use of a dedicated and separate refrigerant circuit with its own evaporative condenser.
Practical Notes	While liquid injection is common practice, it impairs compressor performance by both increasing compressor power and decreasing compressor capacity. The result is lower compressor efficiency.
Other Benefits	Thermosiphon oil cooling also reduces compressor maintenance compared with liquid injection oil cooling. This approach provides opportunities to optimize systems by

	separating oil cooling constraints from system head pressure constraints.
Stage of Acceptance	Thermosiphon oil cooling is a proven technology and has been successful on hundreds of industrial refrigeration systems. Liquid injection has been used widely because of its lower initial cost.
Resources	For information on this best practice see: the IRC's Cold Front Newsletter article: Vol. 3 No. 3, 2003. A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Oil cooling comparison for twin-screw compressors operating at 30.4-psig, 0°F suction and 95°F discharge [IRC 2004].

Compressor	Oil Cooling Case	Capacity [tons]	Power [BHP]	Efficiency [BHP/ton]	Efficiency Penalty
FES Model 315S	Thermosiphon	205.9	340.3	1.65	Base
	Liquid injection	204.7	352.4	1.72	+4.3%
Frick Model RWF 177	Thermosiphon	233.8	375.1	1.60	Base
	Liquid injection	224.5	379.0	1.69	+5.6%

Refrigeration 4 – Dedicated Condenser for Oil Cooling

Best Practice	Traditional systems that reject heat from thermosiphon oil coolers involve integrating the refrigerant-side of oil cooling heat exchangers with the system's high-side. An alternative approach applies one or more dedicated condensers, separate from the system, for the sole purpose of rejecting heat from the oil cooling heat exchangers. The separate refrigerant circuit eliminates the need for non-condensable purging and oil draining required for traditional thermosiphon oil cooling.
Primary Area/Process	This opportunity is for industrial refrigeration systems that use thermosiphon oil cooling for rotary screw compressors.
Productivity Impact	Improves productivity by reducing compressor downtime for operations and maintenance and by reducing the likelihood of high-side liquid surge and liquid feed problems to loads.
Economic Benefit	For a new installation, there is no significant cost difference between a traditional thermosiphon oil cooled system and a dedicated heat rejection condenser(s) for cooling. Payback on a retrofit can range from two years to six years depending on whether or not existing condenser(s) can be used.
Energy Savings	Efficiency benefits vary and can reach 10%. Energy is saved by rejecting heat from the oil at a higher refrigerant temperature.
Applications & Limitations	One of the greatest challenges is overcoming the mindset of "we've never done it that way before."
Practical Notes	Many plants like built-in redundancy. There may be a need to purchase two smaller condensers for oil cooling duty rather than a single larger condenser.
Other Benefits	Dedicated thermosiphon oil cooling offers improved safety and reduced maintenance by eliminating the need to drain oil from the refrigerant-side of oil cooling heat exchangers.
Stage of Acceptance	This best practice has been applied to small systems ranging from cold-storage warehouses to extremely large refrigeration systems serving manufacturing facilities.
Resources	For information on this best practice see: the IRC Newsletter, the Cold Front, "Closed Refrigerant Circuit for Screw Compressor Oil Cooling", Vol. 3, No. 1, 2003. A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 5 – Screw Compressor Sequencing

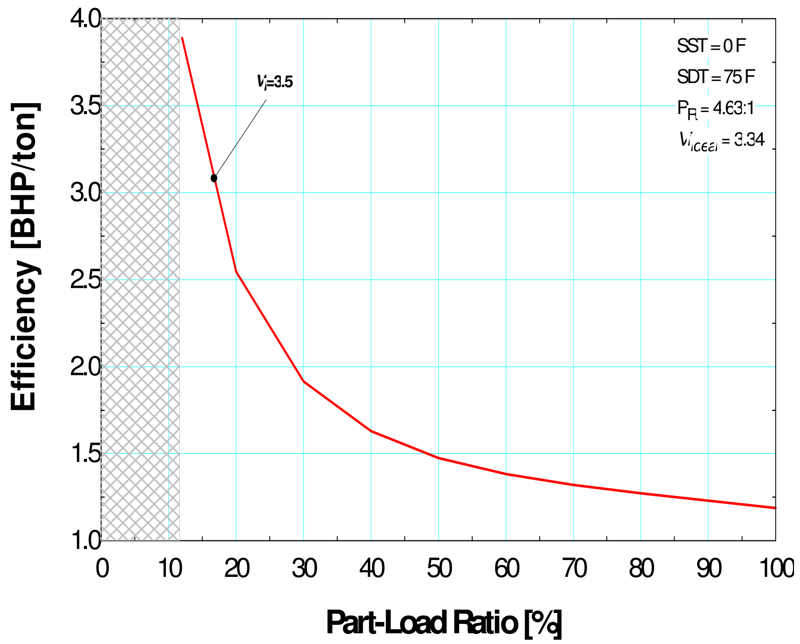
Best Practice	The best efficiency point for fixed speed-drive screw compressors occurs at full-load conditions. As a screw compressor is unloaded to maintain suction pressure at reduced system loads, the efficiency of a screw compressor decreases. Depending on the part-load operating condition, the reduction in compressor operating efficiency can be significant. Sequencing screw compressors can improve energy efficiency significantly.
Primary Area/Process	This strategy applies to all industrial refrigeration systems that use single- or twin-screw compressors in either single-stage or two-stage compression arrangements.
Productivity Impact	Since compressors are the single largest consumer of primary energy (usually electricity) in a refrigeration system, identifying strategies to achieve their efficient operation is essential. Since refrigeration loads vary over time, the capacity of compressor(s) serving those loads must vary in order to maintain a desired suction pressure (temperature) level. Since industrial refrigeration systems generally have multiple compressors available and operating to meet loads, a number of strategies to sequence their operation exist. Unfortunately, some sequencing does not lead to efficient system operation.
Economic Benefit	Improved sequencing can reduce refrigeration system energy consumption. In addition, improved operating sequences can reduce wear on screw compressors equipped with mechanism-based capacity controls such as slide-valve control. Payback varies with opportunity.
Energy Savings	Each industrial refrigeration system's equipment layout is unique so that rules-of-thumb are impractical. For example, a twin-screw compressor that operates at 25 psig suction pressure and 125 psig discharge pressure will have a full-load efficiency of approximately 0.9 BHP for each ton of refrigeration delivered. When unloaded to 50% of full-load capacity, that machine requires 20% more power (1.08 BHP per ton). Operating at its minimum load of around 10%, that same machine will demand 2.74 BHP for each ton of refrigeration delivered (a 204% increase). Therefore, operate screw compressors at full-load to the extent possible.
Applications & Limitations	Virtually all dairy plants use multiple compressors in their refrigeration systems. During the last decade, the use of twin-screw compressors has increased. Therefore, controlling the sequencing of multiple-screw compressors is an opportunity in every plant. Outdated controls technology that exists in many plants may limit this opportunity. Modern computer-based

controls are essential to take full advantage of improved compressor sequencing for peak performance.

Practical Notes

To determine if improving compressor sequencing is of value to you, as you make normal rounds, note the slide valve position of the screw compressors operating (slide valve position is related to the machine's operating part-load condition). If there are one or more machines operating at slide valve positions less than 70%, you likely have an opportunity.

The plot below illustrates the degradation in the efficiency of a twin-screw compressor equipped with slide valve capacity control operating at a suction temperature of 0°F and a saturated discharge temperature of 75°F. At full-load, the compressor requires about 1.2 BHP per ton of refrigeration. When the machine is unloaded to 50% of its full-load capacity, the power required increases to 1.5 BHP per ton of refrigeration. At minimum load (12%), the machine's power requirement rises to 4.0 BHP per ton of refrigeration. Operating efficiency declines with part-load conditions.



The key objective in optimizing the sequencing and control of screw compressors is to avoid prolonged operation of each machine at part-load conditions of less than 65%.

Other Benefits

By raising suction pressure, the compression ratio on high stage and single stage compressors is lowered leading to reduced compressor wear and extended compressor life.

Stage of Acceptance

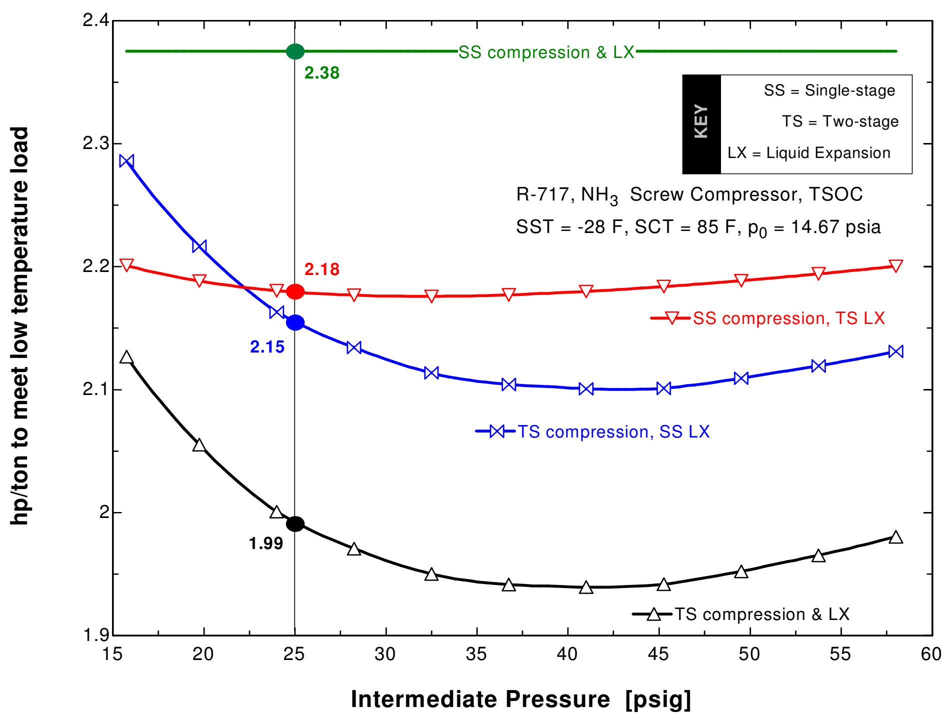
Optimizing the sequencing and controls for twin-screw compressors is readily achievable and effective in improving refrigeration system energy efficiency.

Resources	For information on this best practice see the IRC's TechNote titled: Selection of Screw Compressors for Energy Efficient Operation A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 6 – Manage Liquid Make-up

Best Practice	Consider how to best manage the flash gas created by throttling liquid from higher to lower pressures in refrigeration systems that operate with more than a single low pressure level in the plant. Proper piping practices can improve energy efficiency by as much as 8%. As the difference increases between the upstream liquid supply temperature and the downstream saturation temperature, the amount of liquid supply that will flash to a vapor state (flash gas) during the throttling process increases. Although flash gas is not entirely avoidable, proper application of piping principles and practices can minimize the energy impacts on system performance.
Primary Area/Process	Many industrial refrigeration plants have multiple suction pressure levels to meet loads. Where a plant has medium- and low-temperature loads, there exist advantageous practices in cascading the make-up liquid through progressively lower pressure (temperature) levels within the system.
Productivity Impact	Expect to see a slight increase in refrigeration system productivity.
Economic Benefit	While dependent on system operating pressures and temperatures this best practice can improve efficiency by between 5% and 10% with paybacks ranging from less than one year to three years.
Energy Savings	Consider a two-temperature level refrigeration system where the high temperature loads are served by a 25 psig suction pressure (corresponding to a saturation temperature of 12°F) and the low temperature loads are served by a 0 psig suction pressure (-28°F). Two compression configurations are possible. The first is a system with split suction pressure levels – each having single-stage compression and both compressors discharging to a common high-side pressure. The alternative configuration is to create a compound or two-stage compression arrangement where the low temperature compressor (booster) operates at 0 psig suction and discharges to an intercooler at the 25 psig suction pressure. A high-stage compressor then raises the vapor at the 25 psig suction pressure to a discharge pressure that may range from 110 psig to 181 psig – depending on ambient conditions. In addition to the compressors, the supply of liquid make-up to both the low- and medium-temperature loads must be considered. One arrangement is to have high pressure liquid serve both the medium- and low-temperature loads.

Alternatively, you can throttle the high pressure liquid first to the medium temperature level (25 psig) and then throttle that “precooled” liquid to the low temperature level of the plant. This piping arrangement has the advantage of reducing the flash gas load on the low temperature compressor. What’s the efficiency advantage of multiple stages of liquid throttling? Consider the following plot that shows the individual impact of two components of the efficiency improvement for multi-stage systems: 1) the impact of compressor efficiency, and 2) the impact of multiple stages of liquid expansion.



First, let’s evaluate the impact of system efficiency by comparing the number of stages of compression (both single-stage (SS) and two-stage (TS) with the same number of stages of liquid expansion (LX). For example, compare the HP per ton of a system with a single-stage of compression with two-stages of liquid expansion compared to that of a system with two-stages (TS) of compression and TS of liquid-expansion (LX) at an intermediate pressure of 25 psig:

SS compression with TS LX 2.18 HP/ton
TS compression with TS LX 1.99 HP/ton

That is a 10% improvement in efficiency simply from going from single stage to two-stages of compression.

Now, compare the efficiency of a system with TS compression with TS of LX compared to that of a system with TS compression and SS of LX at an intermediate pressure of 25 psig:

TS compression with SS LX	2.15 HP/ton
TS compression with TS LX	1.99 HP/ton

That is about an 8% improvement in efficiency based on the stages of LX alone.

When possible, take advantage of each temperature level in the plant and throttle liquid, successively, from higher to lower pressures. If the lowest operating pressure in the plant is 3.5 psig (-20°F), consider multiple stages of compression as well.

Applications & Limitations	This best practice applies to plants with refrigeration loads at multiple temperature levels where those loads are served by compressors operating at multiple suction pressures.
Practical Notes	If the lowest operating pressure in the plant is 3.5 psig (-20°F) or lower, strongly consider implementing two-stages of compression (if not already equipped). If the plant has multiple suction pressure levels with single-stage compressors serving each, consider piping the make-up liquid in series from the highest to the lowest pressure level. In cases where there will be one or more intermediate pressure levels in the plant that may not operate, provide alternative means to get liquid make-up to lower temperature loads.
Other Benefits	None noted.
Stage of Acceptance	This practice is well established and adopted in many installations. Some plants have not fully taken advantage of this opportunity.
Resources	A number of resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 7 – Two-Stage Compression

Best Practice	Consider implementing two (or more) stages of compression for refrigeration systems that require operation at temperatures below -20°F.
Primary Area/Process	Multi-stage compression refrigeration can apply to all industrial refrigeration requiring low temperature refrigerant to meet space or process load requirements.
Productivity Impact	No impact on productivity.
Economic Benefit	While retrofits can be done, they can be expensive. The best time to consider a two-stage compression arrangement is early in the process of planning for a new refrigeration system. For new construction, the payback for a two-stage arrangement can range from one year to three years. As the lowest temperature in the plant decreases, the payback shortens.
Energy Savings	Two-stage compression splits the compression process into two distinct steps. As the refrigerant temperature requirement decreases (i.e. lower temperatures), the efficiency gain achieved by moving to two-stage compression from a single-stage increases. For a 28°F load the efficiency improves by 15%. If the load requires -45°F refrigerant, the efficiency gain will exceed 25%.
Applications & Limitations	
Practical Notes	
Other Benefits	For low temperature refrigeration systems, conversion from a single-stage to two-stage compression will prolong the life of the compressor by substantially reducing the compression ratio of the single stage machine.
Stage of Acceptance	Two-stage compression systems have been used to meet low temperature refrigeration needs for more than a century. The technology is well established and proven.
Resources	For information on this best practice see: the IRC's Industrial Refrigeration Energy Efficiency Guidebook 2004. A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 8 – Free Cooling

Best Practice	Free 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 from free cooling comes from allowing automatic controls to turn off the chiller when ambient conditions can meet cooling needs. As a result the economic benefit depends on the chiller load, the electricity rate and the number of hours available for free cooling. Installed costs typically range from about $500 per ton for small (50 to 75 ton) systems to about $325 per ton for larger (greater than 400 ton) systems. Depending on site-specific parameters, paybacks typically range from two years to four years in the upper Midwest.
Energy Savings	Free cooling potential depends primarily on the hours available for free cooling, which is in turn dictated by process temperature requirements. The following can be used as a guide, assuming installation on *fully loaded* chillers in Madison, Wisconsin and a process cooling temperature of 45°F: • 50 ton cooling load: 168,000 kWh per year • 400 ton cooling load: 1,345,000 kWh per year
Applications & Limitations	Free cooling benefits are limited primarily by process temperature requirements, the *actual load* on the chillers and modifications necessary to allow heat rejection to the environment. Existing cooling systems that do not utilize direct refrigerant injection are better candidates than those that do.
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 avoid capacity related issues.
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.
Resources	For more information on this best practice, see the related Wisconsin Focus on Energy Engineering Study in Appendix H.

Refrigeration 9 – Variable Frequency Drives on Evaporator Fans

Best Practice	Many evaporator fans on refrigeration systems operate at constant speed or are cycled for a regular interval. Variable speed fan operation using variable frequency drives (VFDs) can reduce electricity consumption dramatically.
Primary Area/Process	This practice applies to variable torque fan loads.
Productivity Impact	None
Economic Benefit	VFDs are relatively expensive. Payback depends on the amount of time evaporators operate at low part-load conditions. The greater part-load operation, the greater the savings from VFDs.
Energy Savings	At part-load ratio of 50%, VFD control requires 20% less power (kW) per ton of refrigeration, versus continuous fixed speed operation. VFD savings over constant speed operation will likely range from 6% to 10%. Compared with duty cycling at 50%, VFD control requires 9% less power. Savings over duty cycling will range from 3% to 6%.
Applications & Limitations	VFDs excel at part-load conditions, but savings are only realized when the evaporator is operating at part-load. An evaporator that operates close to 100% of load for a significant number of hours per year (perhaps do to frequent stock changes or additions) will see less savings with a VFD than an evaporator that runs more hours at low part-load (perhaps to simply maintain temperature in an existing stock with mild ambient temperatures).
Practical Notes	The easiest way to control evaporator fans is to operate them continuously. This approach maximizes both the direct-fan energy and the parasitic-refrigeration load on the space where the fan operates. A more efficient variation on constant-speed operation is to duty cycle the fans to maintain set-points while eliminating stratification. The most efficient option, VFDs, increase or decrease fan speed as the space temperature deviates above or below set point. Since reducing fan speed reduces torque, the motor power required drops dramatically compared with constant speed operation. By the fan laws, power is related to speed cubed, so that, in an ideal world a 50% reduction in speed reduces power by 87.5%. However, some power (about five%) is used by the VFD.
Other Benefits	Additional potential benefits include fewer system transients, better space temperature control, reduced "wind chill", reduced noise, inherently soft-start and improved power factor.

Stage of Acceptance	Relatively few plants have adopted this opportunity.
Resources	For information on this best practice see: the IRC Industrial Refrigeration Energy Efficiency Guidebook A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 10 – Variable Frequency Drives on Screw Compressors

Best Practice	Screw compressors comprise 80% of the industrial refrigeration market. Staging multiple compressors and the use of a continuous slide valve are two common ways to control compressor capacity. Variable-speed operation with VFDs on the compressor motors can reduce electricity consumption, especially where individual compressors operate a significant number of hours at part-load.
Primary Area/Process	Today's common methods for compressor capacity control are simple, but energy intensive. Constant-speed compressors are least efficient when they are part-loaded or unloaded for a significant amount of time. Variable-speed compressors with VFDs, an efficient alternative, permit capacity modulation through speed adjustment.
Economic Benefit	VFDs in the sizes required to drive screw compressors can be expensive. Payback depends on how much time the compressor is part-loaded, likely within two years to five years.
Energy Savings	Savings over staged or plug-valve capacity control range between 2% and 12% and depend on the existing control strategy and how well it follows load.
Applications & Limitations	VFDs excel at low part-load conditions, but save energy only when the compressor is operating at part-load. A VFD on a compressor operating near 100% load for a significant number of hours per year will see less savings than one that runs more hours at part-load. Consider using only one VFD compressor for each plant suction pressure level.
Practical Notes	VFDs can be beneficial on screw-compressor motors when the compressor is part-loaded for a significant amount of time. Additional compressor efficiency can be achieved by lowering condensing temperature.
Other Benefits	Capacity control with a VFD will reduce wear on slide valves and extend the life of the compressor and critical components such as bearings. Also, a VFD can provide very stable suction pressures.
Stage of Acceptance	Few refrigeration plants have adopted VFDs.
Resources	For information on this best practice see: the IRC Industrial Refrigeration Energy Efficiency Guidebook A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Refrigeration 11 – Variable Frequency Drives on Condenser Fans

Best Practice	Condenser fans on refrigeration systems that primarily operate at constant speed, though they may also be two-speed. Variable-speed fan operation using VFDs can reduce refrigeration system energy consumption significantly.
Primary Area/Process	The condenser on a refrigeration system.
Productivity Impact	None.
Economic Benefit	Payback depends on the amount of time the condenser operates part-loaded. This will depend on weather, refrigeration load and condenser capacity.
Energy Savings	Savings over constant-speed operation will range from 1% to 5%. Savings over two-speed operation is minimal.
Applications & Limitations	VFDs excel under part-load conditions, but save energy only when the condenser has excess capacity or is operating at part-load due to cooler outdoor conditions. There is a trade-off between condenser-fan operation and compressor efficiency because longer condenser-fan operation can help lower condenser temperature, which improves compressor efficiency.
Practical Notes	The basic way to control a condenser fan is on/off control with single-speed operation. This approach is the most energy intensive. A more efficient variation is two-speed fan operation to better match heat rejection capability to outdoor conditions. The most efficient fan control option uses VFDs to increase or decrease fan speed and closely match heat-rejection requirements. Since reducing fan speed reduces torque, the motor power required drops dramatically compared with constant speed operation. By the fan laws, power is related to speed cubed, so that, in an ideal world a 50% reduction in speed reduces power by 87.5%. However, some power (about 5%) is used by the VFD. A system with greater condenser capacity will benefit more from a VFD than one that is short of condenser capacity. Energy savings will be weather-dependent since warm, humid weather requires longer fan run times.
Other Benefits	Minimal fluctuation in system head pressure because the condenser fan motor drive(s) continually modulate the condenser capacity to maintain head pressure. Stable head pressures are a key factor in stabilizing system operation. VFDs also reduce (or eliminate) the starting and stopping of fan motors. Frequently starting and stopping fan motors (as required in strategies that use single and two-speed fans) increases wear on fan belts (if equipped), bearings, shafts and fan blades. Cycling electric motors on and off also

	shortens motor life. Operating condenser fans at reduced speed also decreases drift losses from the condensers.
Stage of Acceptance	Few refrigeration plants have adopted this technology.
Resources	For information on this best practice see: the IRC Industrial Refrigeration Energy Efficiency Guidebook A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Whey Drying 1: Mechanical Vapor Recompression Evaporators

Best Practice	Mechanical vapor recompression (MVR) evaporators can save a significant amount of energy over multi-effect thermal vapor recompression (TVR) evaporators. MVR systems can be purchased as a single effect unit or in some cases retrofitted to existing systems.
Primary Area/Process	Whey processing facilities or cheese plants that concentrate whey to a shippable product using evaporation.
Productivity Impact	No significant production related benefit unless the MVR reduces the load on capacity constrained equipment.
Economic Benefit	The cost of a new or retrofit MVR system can be significant and varies with the compression ratio required and the system capacity. When determining payback from energy savings, assume gas at \$6.00/MMBtu and electricity at \$0.055/kWh. The following is a guide to energy savings: • Two-effect with TVR: \$0.0031/lb water removed • Five-effect with TVR: \$0.0008/lb water removed • Single-effect with MVR: \$0.0002/lb water removed
Energy Savings	Savings vary but the following can be used as a guide: • Two-effect with TVR: 390 Btu/lb water removed • Five-effect with TVR: 130 Btu/lb water removed • Single-effect with MVR: 32 Btu/lb water removed
Applications & Limitations	MVR evaporators are limited to a maximum compression ratio of about 2:1 per stage. Multi-stage systems can be used for higher ratios but this increases first cost.
Practical Notes	While the energy savings from MVR can be significant, the electric motor driven compressor will require maintenance, an additional expense. Account for this when evaluating payback.
Other Benefits	In new installations, the first cost can be lower due to the typically smaller foot print and amount of equipment needed.
Stage of Acceptance	This technology is an accepted best practice and has been used for over 20 years in the dairy industry.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Whey Drying 2 – Spray Dryer Heat Recovery

Best Practice	Recover the large quantity of hot exhaust that is often discharged from spray dryers to preheat incoming process air.
Primary Area/Process	Spray dryers for water based applications.
Productivity Impact	None, unless heat recovery adds useable capacity.
Economic Benefit	Depending on the installation, payback can range from two years to five years. A recent Focus on Energy study indicates a savings of $12.40 per hour on a whey dryer. The gas rate was $0.70 per therm, the exhaust temperature was 180°F with an inlet air-flow rate of 16,000 scfm.
Energy Savings	The energy savings depends on the amount of heat exhausted and on having an appropriate "heat sink," such as inlet air. For the example above, the fuel savings for the installed system was approximately 17.7 therms per hour.
Applications & Limitations	Economic benefits may be limited by the difficulty of the installation and type of heat-recovery system used. Different types include glass-tube exchangers, fin-coil systems with glycol loops and metal-foil exchangers. In some cases, the heat-recovery units must be installed after a filtration device is installed to prevent excessive fouling and sanitation problems. Spray dryer heat recovery requires significant capital so care should be taken to validate the parameters used for estimates.
Practical Notes	Higher fat content materials may be sticky and pose difficulties in cleaning that may in turn limit operating recovery efficiency. Install exchangers where they will not be subject to fouling or use an exchanger that can handle fouling, e.g., glass-tube. Leave design and installation of internal exchanger CIP systems to the equipment suppliers. When having otherwise skilled staff do the task, poor cleaning, plugging and back up of condensate into the process may result.
Other Benefits	None.
Stage of Acceptance	Some poorly designed installations have caused some to view this technology with skepticism. Trouble free installations, in operation for 15-years, are documented in Wisconsin.
Resources	A number of commercial resources exist for this best practice. Contact a Focus on Energy representative listed in Appendix D for additional information.

Concentration 1 – Reverse Osmosis Concentration

Best Practice	Reverse osmosis (RO) is a cost effective way to increase capacity and reduce energy costs related to whey concentration over single- and multiple-effect evaporators.
Primary Area/Process	Processing facilities or cheese plants that concentrate whey.
Productivity Impact	Can effectively increase the volumetric capacity of a whey evaporator, increasing the total solids output.
Economic Benefit	The cost of an RO system varies with the water removal rate. A moderately-sized system can cost between \$100,000 and \$150,000. Sometimes stages can be added to existing systems for a cost of about \$40,000. If gas costs \$6.00/MMBtu and electricity costs \$0.055/kWh, use the following as a guide for energy savings: • Two-effect with TVR: \$0.0031/lb water removed • Five-effect with TVR: \$0.0008/lb water removed • Three-stage RO: \$0.00035/lb water removed *TVR: thermal vapor recompression
Energy Savings	Energy savings vary - use the following as a guide: • Two-effect with TVR: 390 Btu/lb water removed • Five-effect with TVR: 130 Btu/lb water removed • Three-stage RO: 24 Btu/lb water removed *TVR: thermal vapor recompression
Applications & Limitations	RO systems are inherently more energy efficient than most evaporators. RO can provide concentration to levels as high as 24 percent. Consider the potential impact on evaporator hydraulics and the “efficiency” of thermal vapor recompressors. In some cases, modifications may be necessary.
Practical Notes	An existing evaporator to be used after RO must be able to handle the increased solids loading. The maximum final whey concentration from RO is about 24 percent.
Other Benefits	RO is a cost effective means to increase the capacity of the whey concentration system.
Stage of Acceptance	This technology is an accepted best practice and is used extensively in the dairy industry.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information. See following page.

Focus on Energy
Business Programs
Engineering Case Study

CONSIDER REVERSE OSMOSIS TO COMPLEMENT EVAPORATION

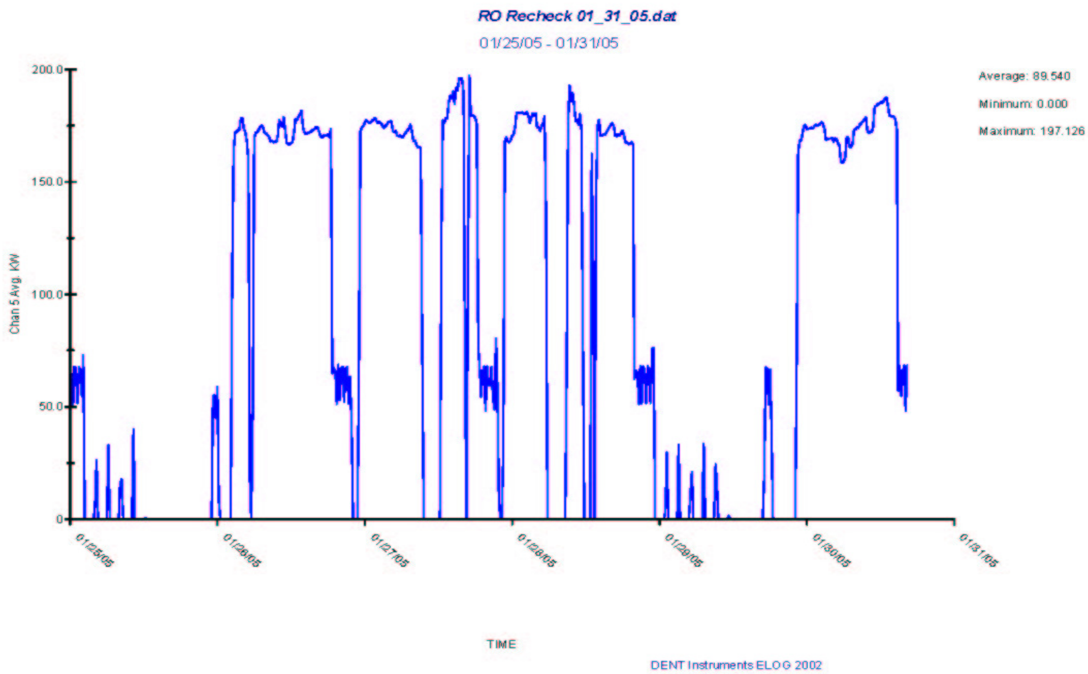
Reverse osmosis (RO) is a membrane-separation process that uses high-pressure pumping instead of evaporation to concentrate product and has much lower energy costs than evaporation. While RO is proven for many industrial applications, this case study addresses the application of RO to whey processing. The following analysis derives from metered data and collaboration with the original process and equipment designers.

Generally, in new design RO can concentrate whey from six percent up to about 24 percent. However, in retrofits where RO is used on the front end of an evaporator, evaporator performance may limit the final concentration unless appropriate modifications are installed. Consider a multi-effect evaporator currently concentrating whey from six percent to 24 percent. The evaporator designer indicates that the upper limit for the whey feed concentration delivered to the evaporator is likely about 12 percent to avoid operational problems. In this case, RO can be used to concentrate whey from six percent to 12 percent. The evaporator can then concentrate the whey from 12 percent to 24 percent

Reverse Osmosis System

The Opportunity

When a Wisconsin dairy learned that a RO system could provide energy savings and increase production, the company decided to evaluate the potential relative to its existing RO system. The existing system was installed in the mid-1990's to increase whey concentration capacity. An evaluation indicated that the solids concentration could be increased by up to 2.5-percent without harm to the RO unit or the performance of the multi-effect evaporator. The evaluation reported that this could be done simply with control set point changes. The evaporation process was modeled with process log data and original system design data to determine the potential energy savings. Since no other reliable way to estimate the steam flow used by the evaporator existed, modeling was used. The RO system was evaluated by metering the main power to the RO system. (see figure below).



This data represents the operation of the RO system during both processing and non-processing periods. The power data printed in the upper right corner shows the *overall* profile. The results of the analysis of the evaporator and the RO system during processing are summarized in the table below.

Current RO and Evaporator Conditions

System	Motive Steam* (lb/hr)	Electric Power (kW)	Btu/lb of water removed	$/lb water removed**
5-effect evaporator with TVR	6,300	0	131	$0.00079
Three Stage RO	0	170	23.6	$0.00035

**Motive steam load adjusted to account for apparent inefficiency of existing TVR. Condensate at 160°F is assumed to result from condensation of the motive steam. All condensate from the evaporator is assumed to be beneficially used elsewhere in process operations.*
*** These numbers include energy costs only. Natural gas at $6.00/MMBtu, electricity at $0.05/kWh and 4,500 hours per year average process operation time. Any water disposal charges have not been included.*
NOTE: Maintenance was 38% higher for evaporation, including chemicals for CIP and membrane costs.

The Solution

The analysis indicated that the water to be removed by evaporation would lessen by about 17 percent, yielding estimated energy savings of over $20,000 per year. Estimated payback is immediate.

Project Benefits

RO can be a very cost effective way both to increase the capacity of a process and to reduce energy costs. Also, in some cases RO may *completely* off-set the need for evaporation where evaporation is used to provide a final concentration of less than 22%.

Steam System 1 – Heat Recovery from Continuous Boiler Skimmers

Best Practice	Often boilers use continuous skimming, also called continuous blow-down, to prevent solids buildup. Since the blow-down often goes to drain, a significant amount of energy is available for recovery.
Primary Area/Process	Low- and high-pressure process steam boilers.
Productivity Impact	None, unless heat recovery adds useable capacity.
Economic Benefit	This practice recovers waste heat from boiler blow-down to preheat boiler make-up water, feed water or process water, to avoid primary heating costs. Typical installations range from \$12,000 to \$18,000. Assuming a 1,200 hp boiler (~45,000 pph), 80% efficiency, at 100-psig, a blow-down rate of four percent and a gas rate of \$8.00/MMBtu, the savings is about \$4.93 per hour.
Energy Savings	In the example above, energy savings are about 615,585 Btu/hr.
Applications & Limitations	The economic benefit is limited by the blow-down rate.
Practical Notes	Some systems already capture latent heat from blow-down flash steam that is used in the de-aerator. When evaluating project economics, you should account for this factor. You may be able to minimize the blow-down rate or shift from intermittent to continuous blow-down to even out the heat transfer rate. Ideally, consider these options up front.
Other Benefits	Preheating make-up or feed water can help reduce thermal shock to the boiler, in some cases reducing stress on tubes.
Stage of Acceptance	This technology is generally understood and accepted.
Resources	For information on this best practice see: ? A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Steam System 2 – Boiler Exhaust Heat Recovery with Condensing Economizer

Best Practice	Industrial process boilers lose 15% to 20% of the fuel heat through stack gases. Condensing economizers can be used to cool and condense the exhaust water vapor, increasing boiler efficiency 5% to 10%.
Primary Area/Process	Low and high pressure process steam boilers.
Productivity Impact	None unless heat recovery adds useable boiler capacity.
Economic Benefit	This practice recovers waste heat from stack gases to preheat boiler make-up water, feed water or process water, avoiding primary heating costs. Paybacks range from one year to three years depending on the type of condensing economizer used and the fuel rate. Direct contact units are less expensive than indirect contact units. Assuming an average steam rate of 20,000 pph, a pressure of 100-psig and a rate of $8.00/MMBtu, a 10 percent efficiency gain yields about $17.60/hr.
Energy Savings	Energy savings depend on the quantity and temperature of condensing medium available and the temperature requirements of the water leaving the economizer. In the example above, a 10 percent efficiency gain saves about 2.2 MMBtu/hr.
Applications & Limitations	Some operators resist direct contact systems because the flue gas comes in contact with the condensing water, entraining some of the flue gas constituents. This is a concern with systems that can fire fuel oil or natural gas and can be addressed by incorporating a separate heat exchanger.
Practical Notes	Depending on temperature requirements, one particular system may be better than the other. Since condensing economizers *cause* condensation, they are designed to handle corrosion and are not subject to the cold-end condensation problems common to non-condensing feed water economizers.
Other Benefits	Preheating make-up or feed water can help reduce thermal shock to the boiler, in some cases reducing stress on tubes.
Stage of Acceptance	This technology is not widely understood but is gaining in popularity due to rising fuel prices.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Steam System 3 – Initiate a Steam Trap Program

Best Practice	Scheduled checking of steam traps has been considered a best practice for many years. The repair and replacement of leaking traps can significantly reduce steam costs.
Primary Area/Process	High and low pressure non-pressurized condensate return systems.
Productivity Impact	None unless leaking traps allow enough steam to be lost to impact process operations due to reducing effective capacity.
Economic Benefit	An inverted bucket trap with a ¾-inch body and ¼-inch orifice will pass about 700 pph of live steam in a failed open position. Assuming that each pound of steam passing the trap leaves the steam system, a fuel at $7.00 per MMBtu and a boiler efficiency of 80 percent, this costs $7.00 per hour. In a *process* operating 4,000 hours per year, the leaking trap is responsible for a cost increase of $28,000.
Energy Savings	For the example, the energy loss is about 1.01 MMBtu/hour.
Applications & Limitations	This best practice applies to any steam system with a vented-condensate collection system. Although all traps can fail open, target inverted bucket and disc traps first since they tend to fail open.
Practical Notes	Electronic equipment can help determine if a steam trap has failed open. However, for a proper diagnosis, find out what type of trap is being evaluated. Make a "map" of your facility that indicates the type of trap, make, age, body size and orifice size. Look at the stack on the condensate vent tank. A normal condition is usually indicated by a gentle wafting of steam from the stack (this is flash steam). High velocity steam usually indicates one or more traps passing live steam.
Other Benefits	None.
Stage of Acceptance	Improving exchanger performance is well documented and accepted.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

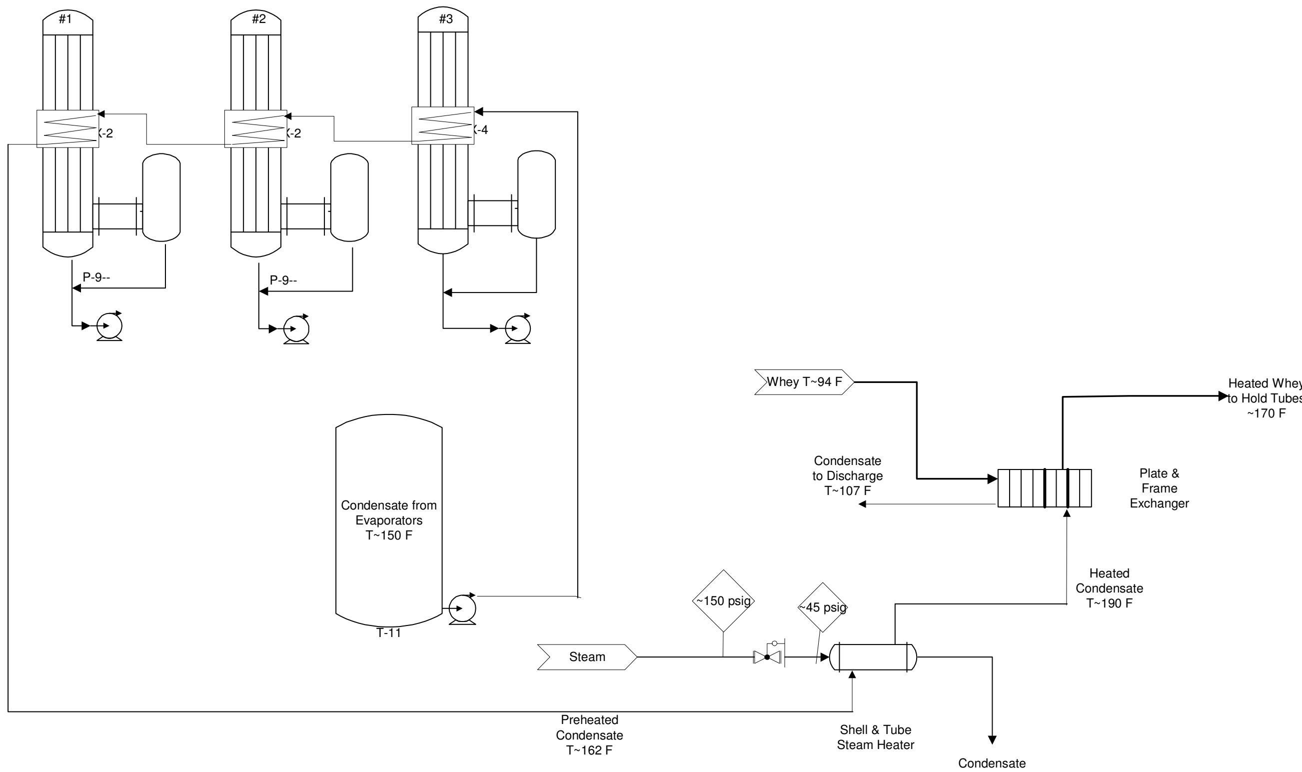
Steam System 4 – Boiler Pressure Reduction

Best Practice	Many dairy facilities generate steam at higher pressure and reduce the pressure to match the load for a particular unit operation. Lowering boiler steam generation pressure to better match process requirements will reduce energy costs about 1% for each 40°F drop that stack temperature can be lowered.
Primary Area/Process	Low- and high-pressure steam plant boilers
Productivity Impact	None.
Economic Benefit	Generally, payback is immediate if controls or other equipment do not require modification or replacement. Payback depends on the size of the boiler and the amount of turn-down possible. A recent application on a 200-hp boiler allowed turn-down from 110-psig to 60-psig, for a cost savings of $3,120 per year at a fuel rate of $9.00 per MMBtu.
Energy Savings	For the example above, the energy savings were estimated at 347 MMBtu per year.
Applications & Limitations	Reducing pressure too much can cause carry over resulting in wet steam. Incremental reductions are recommended, with guidance from the manufacturer as necessary.
Practical Notes	Since stack temperatures are usually 50°F to 100°F above steam temperature, savings can be easily estimated from the difference in steam temperatures. For the example above, the temperatures of 110 psig and 60 psig steam are approximately 344ºF and 308ºF, respectively.
Other Benefits	Less heat loss in the steam distribution system.
Stage of Acceptance	This technology is widely understood.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

Process Heat 1 – Select Proper Heat Exchanger for Pasteurizer

Best Practice	Pasteurizers typically use a heat exchanger to heat water for pasteurization of whey, raw mixes and milk. Depending on your system configuration and type of exchanger, you may be able to replace the existing heat exchanger with one that allows a lower approach temperature and still meets production needs.
Primary Area/Process	Any system that uses pasteurization.
Productivity Impact	Usually none, unless the hot water temperature can be reduced, minimizing the chance of "burn on."
Economic Benefit	Payback depends on lowering energy costs for water heating, reduced pump pressure drops or flow rates. A Focus on Energy study showed a savings of $4.44 per hour at $6.00 per MMBtu and a boiler efficiency of 80%. Payback, based only on the thermal energy savings, was estimated at 2.5 years.
Energy Savings	Lowering the "approach temperature" by improving the heat exchanger can save thermal energy, especially if the outlet hot water is discharged to the drain. In the study mentioned above, the energy savings were estimated at 740,000 Btu per hour. Reducing flows through throttling or using VFDs may allow a reduction in electricity used.
Applications & Limitations	Shell and tube exchangers generally offer more opportunity for improvement than plate and frame exchangers. However, plate and frame exchangers can also be improved.
Practical Notes	Make sure that reducing the inlet hot water temperature will actually provide a reduction and not just shift the load from one point to another.
Other Benefits	Reducing hot water temperatures can reduce "burn on" of minerals on the product side of the exchangers.
Stage of Acceptance	Improving exchanger performance is well documented and accepted.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

The pasteurization of whey is an energy-intensive process that heats whey to approximately 170°F, usually in a large plate and frame heat exchanger. The heat source is usually condensate from the whey concentration process, such as from evaporation. Since the condensate temperature ranges from 140°F to 160°F, it must be heated to about 185°F to 190°F before entering the plate frame exchanger. A simplified illustration of the pasteurization process is shown below.



Typical Pasteurizer Used in Conjunction with Multi-Effect Evaporation.

Once process needs have been met, a plate and frame heat exchanger, like other process equipment, is frequently purchased because of low first-cost. Often, the selected heat exchanger is not efficient. For this case study, an efficient exchanger is one that can use a lower temperature source and still raise the whey temperature to that which is required for pasteurization.

Heat exchanger efficiency is usually expressed in terms of its approach temperature or "effectiveness." Reducing the approach temperature improves the heat exchanger efficiency. As a rule, plate and frame heat exchangers are capable of a lower approach temperature than shell and tube exchangers. However, even plate and frame heat exchangers can be improved.

The Opportunity

A Wisconsin dairy facility wanted to identify process energy efficiency opportunities and replacement of the whey pasteurizer heat exchanger was identified as a potential opportunity. The heart of the pasteurizer is the plate and frame heat exchanger shown in the illustration shown on page -. The original exchanger was installed with low first-cost in mind. After years of operation, one of the plates had developed a leak and was scheduled for replacement. However, after looking at performance parameters, v it was determined that the approach temperature was much higher than possible for this type of unit. The high approach temperature also required a higher water temperature for heating the whey, which caused whey burn-on. Furthermore, a large amount of potentially useful energy was being carried away in the wastewater.

The Solution

Since the water passing through the heat exchanger is sent to the drain after heating the whey, lowering the approach temperature of the COW water would have the effect both of saving energy and of reducing the risk of whey burn-on. The facility elected to replace the entire heat exchanger rather than replace only a single plate. This decision was based largely on production improvements and on the long expected lifetime of the equipment. Plus, the economics made sense. The existing heat exchanger temperatures, projected temperatures and expected energy savings are provided in the table below.

Parameter	Existing	Projected
COW water temp (^oF)	190	185
Whey entering temp (^oF)	162	162
Energy savings (MMBtu/hr)	-	0.763

Project Summary	
Project Cost (est)	$65,000
Energy Savings (est)	$24,000
nergy Payback	2.7 yrs

Project Benefits

The table above indicates that replacement of the existing plate and frame heat exchanger with a unit that allows a lower hot COW-water temperature for whey pasteurization can save energy. In addition to saving an estimated 4,119 MMBtu per year, the lower approach-temperature reduces the chance for whey burn-on. Reducing burn-on potential not only helps with product quality, but it also helps prevent fouling and related energy increases that result as controls try to overcome the increased resistance to heat-flow.

At $6.00/MMBtu, the new equipment provides an estimated annual savings of $24,000 with a simple payback of 2.7 years. This payback does not include additional dollars from a Focus on Energy incentive, which encouraged the facility to install the new pasteurizer exchanger.

Note: If the hot water leaving the pasteurizer was already used elsewhere in the process, some, or all, of the potential savings may not have been realized. Only careful process analysis can ensure the likelihood of projected savings.

General 1 - Metering and Monitoring for Energy Efficiency and Cost Reduction

Best Practice	Metering and monitoring refers to the use of portable or permanent devices to provide selected information about a process stream or piece of equipment. The information tracked usually includes energy (kWh), power (kW), flow, flow rate, temperature and pressure.
Primary Area/Process	This best practice applies to any energy conversion process, including manufacturing, production and building technologies.
Productivity Impact	Production impacts are possible, depending on the application.
Economic Benefit	A Wisconsin dairy considered replacing the variable frequency drive (VFD) on a mechanical vapor recompressor (MVR). Since the VFD was 20 years old, the operators thought a new drive would be more efficient. Power metering showed that replacing the drive would offer no gain in efficiency. The facility avoided $50,000 in drive replacement costs.
Energy Savings	Metering and monitoring provide no *direct* energy savings unless the results are used to make the indicated improvements. Energy savings will vary with the indicated improvement.
Applications & Limitations	Metering and monitoring data can be done by itself or in conjunction with simple estimates or detailed engineering analysis to determine value of potential projects.
Practical Notes	In some cases, application of metering and monitoring will require "strategic" planning to determine the best locations for meters and the best way to use and present the data.
Other Benefits	With proper placement, metering and monitoring can also be used to help develop awareness and allocate utility costs at facilities that use "business units" or cost allocation centers.
Stage of Acceptance	This technology is generally accepted as the most effective method to determine actual energy savings and to determine which areas of a facility or process are most appropriate to target for efficiency improvement activities.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information. Local utilities often also help in simpler applications. See engineering study summary on page 51.

Focus on Energy
Business Programs
Engineering Case Study

METER & MONITOR TO VERIFY SAVINGS BEFORE IMPLEMENTATION

Metering and monitoring refer to the use of portable or permanent devices to provide selected information about a particular process stream or piece of equipment. The information to be tracked depends on what it will be used for but also, can include electricity use (kWh), power (kW), total flow, flow rate, temperature and pressure. These parameters may be metered for a short time to obtain a snap shot or monitored for an extended period to provide baseline information about how a process or piece of equipment is operating. This type of information can be very valuable on a stand-alone basis or when used in conjunction with simple estimates or advanced analysis to identify the economic value of potential projects. In some cases, it can also be used to help develop awareness and to understand the allocation of utility costs. This case study reviews three specific projects considered at Wisconsin dairy facilities where metering was used.

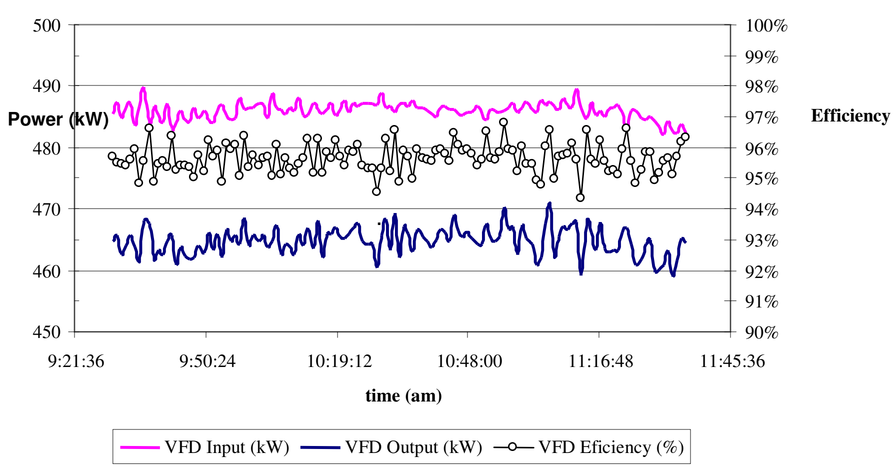
Opportunity 1 - *Variable Frequency Drive Efficiency*

A medium- to large-size Wisconsin dairy facility was considering the replacement of the existing variable frequency drive (VFD) on the mechanical vapor recompressor (MVR) used on their multi-effect evaporator. The unit was roughly 20 years old and operators believed that a newer drive would be more efficient.

Solution

Two Dent ElitePro three-phase logging power meters were used to determine the operating efficiency of the drive. One was placed on the AC line to the VFD and the other between the VFD and the MVR motor. The two meters were synchronized. Figure 1 below summarizes the results of the metering.

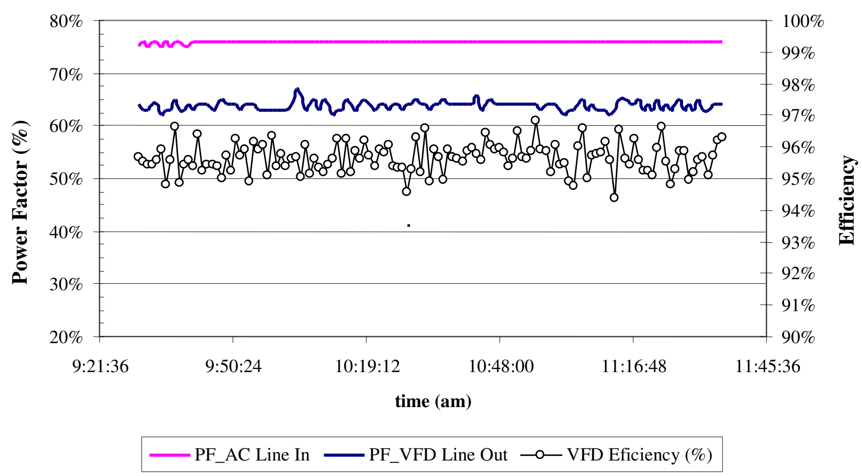
Figure 1. VFD Efficiency



The monitoring over this period showed that the VFD efficiency was satisfactory - well within the expected range, even for a new drive. Replacing this drive on the basis of efficiency would, very likely, provide no energy savings. Since the new drive would cost between $50,000 and $60,000, it would not be cost-effective. Often equipment that has been in service for many years can wear and perform at a lower efficiency than when new. The staff's willingness to perform this assessment saved the company the considerable investment in a new VFD.

Metering also helps address power factor correction, often linked to the use of VFDs. Significant power factor charges from the electric utility can motivate a facility to correct its power factor. Figure 2 on page 53 clearly shows the positive impact that the VFD has on power factor. In other applications, metering has shown that VFDs can improve power factor from about 60 percent to as high as 92 percent.

Figure 2. Power Factor



Opportunity 2 – Exhaust Heat Recovery

Process heat recovery systems can be expensive. Often these systems are purchased and installed based on design assumptions, nameplate equipment data or using data from process control rooms. Often, the actual conditions that a heat recovery system "sees" can vary considerably from these assumptions. Sometimes process flows are overlooked due to the complexity of the processes involved, inadequate instrument calibration, substantially oversized equipment or equipment that is not operating at design because it is worn from years of reliable service without the need for maintenance.

Solution

Table 1 gives an example where metered data were considerably different from anticipated values. Note the impact on hourly savings. The discrepancy was initially identified through engineering modeling of the process, with metered data as inputs. The "missing" flow was identified after the discrepancy was found. Though this is a very good project, future efforts can suffer when anticipated savings are too far from what is realized. While it is sometimes very difficult to verify energy savings, particularly with the utility meter as the guide, efforts up front can help ensure that accurate data are used in assessing projects.

Table 1. Anticipated vs. Meter-Validated Data

Parameter	Anticipated	Measured / Validated
Annual Operating Hours	7,280	**6,934** (BIN data)
Inlet Air-Flow Rate (scfm)	40,700	**15,984**
Exhaust Temperature (F)	195	**178.3**
Exhaust Air-Flow Rate (scfm)	45,515	**38,074**
Exhaust Temperature Leaving Exchanger (F)	109	**138.3**
Preheated Air Temperature (F)	138.4	**~148**
Hourly Energy Savings (therm/hr)	40.6	**17.7**
Hourly Energy Cost Savings ($/hr)	$28/hr	**$12.40/hr**

General 2 - Replace Old Agitator Motors

Best Practice	Many dairy facilities still use motors on agitators that are older and inefficient compared with current models. Since agitator motors often operate near full load, it often makes economic sense to replace the motor with a premium version.
Primary Area/Process	Whey pasteurization and other mixing applications.
Productivity Impact	None
Economic Benefit	The benefit comes from using a higher efficiency motor. Typical paybacks range from two years to three years depending mostly on operating hours. A 20 HP agitator motor with a nameplate efficiency of 87.5 percent can be replaced with a premium motor with an efficiency of 93%. With 6,000 annual hours of operation, a load factor of 90% and an electric rate of $0.05/kWh, the energy savings is $272 per year and the simple return on the motor cost is 2.7 years.
Energy Savings	In the above example, the energy savings is 5,446 kWh per year.
Applications & Limitations	Non-agitator motors are also candidates. Older motors that are larger than 75 HP may already have relatively high efficiencies and replacement may be less economically beneficial.
Practical Notes	Older motors ready for replacement will offer better returns because they will need replacement regardless. Where smaller motors (< 10-HP) are substantially part loaded, the economic benefit will be greater due to the poor part load efficiency of smaller motors.
Other Benefits	None.
Stage of Acceptance	This technology is widely understood and is generally utilized.
Resources	A number of commercial resources exist for this technology. Contact a Focus on Energy representative listed in Appendix D for additional information.

APPENDIX A
Summary Checklist for Dairy Processing Plant Energy Best Practices – Page 1

Best Practice Analyzed (Date)	Further review Needed? Yes/No	Best Practice Possible? Yes/No	Area	#	Title	Typical ROI
			Refrigeration	1	Reset Floating Head Pressure Control	>100%
			Refrigeration	2	Raise Suction Pressure	>100%
			Refrigeration	3	Screw Compressor Oil Cooling Conversion: Liquid Injection to Thermosiphon	20%-30%
			Refrigeration	4	Dedicated Condenser for Oil Cooling	30%-50%
			Refrigeration	5	Screw Compressor Sequencing	>100%
			Refrigeration	6	Manage Liquid Make-up	25%-80%
			Refrigeration	7	Two-Stage Compression	10%-50%
			Refrigeration	8	Free-cooling	25%-50%
			Refrigeration	9	VFDs on Evaporator Fans	40%-80%
			Refrigeration	10	VFDs on Screw Compressors	40%-80%
			Refrigeration	11	VFDs on Condenser Fans	40%-80%
			Whey Drying	1	Mechanical Vapor Recompression Evaporators	20%-30%
			Whey Drying	2	Spray Dryer Heat Recovery	15%-50%
			Concentration	1	Reverse Osmosis Concentration	10%-50%
			Steam System	1	Heat Recovery from Continuous Boiler Skimmers	>100%
			Steam System	2	Boiler Exhaust Heat Recovery with Condensing Economizer	30%-100%
			Steam System	3	Initiate a Steam Trap Program	>100%
			Steam System	4	Boiler Pressure Reduction	>100%
			Process Heat	1	Select Proper Heat Exchanger for Pasteurizer	20%-50%
			General	1	Metering and Monitoring for Energy Efficiency and Cost Reduction	n/a
			General	2	Replace Old Agitator Motors	30%-50%

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 project incentives, contact 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 verses 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

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 blow-down		Use of free cooling - cooling tower
	Insulate pipes		Match chilled water pumps
	Improve boiler efficiency		Insulate pipes and vessels
	Heat recovery for boiler blow-down		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

REFRIGERATION ENERGY EFFICIENCY IMPROVEMENT POTENTIAL CHECKLIST
(Courtesy of the Industrial Refrigeration Consortium)

COMPRESSORS

- ☐ **Reduce Head Pressure**
  - ☐ **Floating Head Pressure**
  - ☐ **Fixed Head Pressure**
  - ☐ **Winter Operation**
    - ☐ **120 psi and below**
    - ☐ **121 – 150 psi**
    - ☐ **151 – 180 psi**
    - ☐ **181 psi and above**
  - ☐ **Summer Operation**
    - ☐ **150 psi and below**
    - ☐ **151 -180 psi**
    - ☐ **181 psi and above**
- ☐ **Raise Suction Pressure**
- ☐ **Compressor Sequencing**

OPERATIONS

- ☐ **Implement Load Shifting**
  - ☐ **Review Utility Rate Structure**
  - ☐ **Battery-charging Off-peak**
  - ☐ **Others______________________________**
- ☐ **Improve Defrost Control Strategy**
  - ☐ **Defrost Off-peak**
  - ☐ **Stagger Defrost**
  - ☐ **Optimize Defrost Time/Energy Input**
  - ☐ **On a Need-basis Rather than Timed**

Compressors

Reduce Head Pressure

There are a number of reasons why compressor discharge pressure (head pressure) can be artificially high. Some quick checks include:

- Condenser
- Defrosting
- Direct-expansion evaporators
- Liquid injection oil cooling
- Screw compressor oil separator sizing
- Evaporative condenser selection
- Compressor selection
- High-pressure liquid piping
- Hand expansion valve settings
- Gas-driven equipment
- Controlled-pressure receivers
- Heat recovery

Look at the condenser:

- Fans
  - □ Are they all working?
  - □ Do you have variable or multi-speed fans?
    - □ Are they used to control head pressure?
  - □ Is there anything blocking fans from effectively moving air?
    - Walls
    - Blocked/bent/scaled louvers
  - □ Are the fan drive systems in good working order?
    - Shaft/shaft bearings
    - Motor
- Coils
  - □ Are the coils free of debris?
    - Biological/scale build-up
    - Clean coils semi-annually if this is a problem
  - □ Do you have an evaporative condenser?
    - □ Are all of the coils being wetted?
      - □ Intermittently wetted?
        - Look for severe scaling here
      - □ Dry spots?
        - Check spray nozzles for obstruction
        - Consider adding more nozzles if necessary

What are your hot gas defrosting requirements?

□ Do you have defrost relief valves that open at 75+ psi?
- Consider lowering this pressure if defrost time remains within specification

□ Are your defrost supply mains and evaporator run-outs undersized?

    - Pressure drop in defrost lines can be a limiting factor to further dropping head pressure

□ Do you use direct-expansion (DX) evaporators?
- The thermostatic expansion valve (TXV) commonly requires a 75 psi pressure drop across it, which can limit the minimum head pressure allowed
    - Consider swapping TXV for electronic expansion valves or a motorized valve
    - Consider swapping out evaporators for liquid overfed or flooded evaporators

□ Do you use liquid-injection oil cooling?
- Liquid-injection oil cooling (SOC) typically requires 100 psi pressure difference across the TXV, which can limit head pressure to around 130 psig.
    - Consider using thermosiphon oil cooling

□ Is your oil separator adequately sized?
- Lower head pressures will result in higher gas velocity through the oil separator at full-load conditions
    - If oil separation becomes a problem during low-head, full-load operation, consider upsizing the oil separator to decrease gas velocity through it and allow the oil to fall out.

□ Is your evaporative condenser adequately sized?
- If you are not meeting load at a given lowered head pressure, you may have undersized condensers and will have to maintain a higher head pressure until there is more condenser capacity. (Condenser sizing is discussed in more detail in Sec. 4.2 in the IRC Energy Efficiency Guidebook)

□ Does your compressor have a fixed or variable volume ratio (Vi)?
- If you have a fixed Vi screw system and the compressor discharge pressure is severely mismatched with the operating high-side pressure, an energy penalty will be incurred.

  (Note: Screw compressors are the only compressor type having such a constraint.)

□ Are your loads fed with high pressure liquid?
- Your ability to supply evaporatprs with cold liquid will diminish with decreasing head pressure. It may become necessary to artificially pressurize the high pressure liquid supply line to achieve the necessary flow rate into the evaporators.

□ As head pressure drops, are hand expansion valves set properly?
- The pressure drop requirement across the hand expansion valve decreases with falling head pressure. Manual reset of hand expansion valves may become necessary in order to meet load.

□ Do you have pumper drums (gas driven liquid transfer systems)?

- The ability to transfer liquid using pumper drums becomes diminished as head pressure drops. In order to safely transfer liquid and continue to decrease head pressure, it may be necessary to change to a liquid refrigerant pump.

□ Do you have controlled pressure receivers (CPRs)?
- It may become difficult to maintain pressure in a CPR while decreasing head pressure.
  - Pressure regulator may not be sufficiently sized.
  - Try adding a separate parallel valve train with an alternative regulator selection that is activated when head pressure drops.
  - May want to consider substituting CPR for a mechanically pumped recirculator package

□ Do you run into heat recovery problems as head pressure falls?
- If heat recovery is an obstacle that does not allow head pressure to drop, consider generating heat elsewhere rather than penalizing the entire refrigeration system. The penalty associated with maintaining head pressure for heat recovery far outweighs that of heat generation.

Raise Suction Pressure

Raising suction pressure is more complicated because it may have a direct impact on product quality depending on the application. The benefits of raising suction pressure are substantial, however. An increase in suction pressure by 1°F can increase compressor capacity by about 2.5%, as a rule-of-thumb. Thus, it may be worthwhile to check suction pressure three or more times per day to set it at a maximum while still provide sufficient cooling.

The following are potential constraints of raising suction pressure.

- Compressor motor sizing
- Oil separator sizing
- Suction line pressure drop
- Vessels
- Valves

□ Is your compressor motor sized such that it will be able to handle full load conditions with an increase in suction pressure?
- Often a motor will be over-sized for a compressor at initial design suction pressure, but it is important to make sure the motor is sufficient for full load conditions at higher suction pressures.
  - If it is not, consider changing the maximum slide stop position, so that compressor full design load is never met.
  - If you have a belt-driven system, consider changing a pulley to keep motor load lower.

□ Is your <u>oil separator</u> adequately sized?

- Lower head pressures will result in higher gas velocity through the oil separator at full-load conditions
    - If oil separation becomes a problem during low-head, full-load operation, consider upsizing the oil separator to decrease gas velocity through it and allow the oil to fall out.

□ Are your <u>suction lines</u> adequately sized?

- Utilizing increased compressor capacity as suction pressure is reduced will result in higher pressure drop in suction lines. Undersized suction lines will penalize a portion of the efficiency gains realized by increasing suction pressure. (Note: Under the same mass flow conditions at higher suction pressures, pressure drop will actually fall.)

□ Are your <u>vessels</u> adequately sized?

- If you are raising suction pressure for improved energy efficiency only, then vessel sizing should be adequate as is. However, if by raising suction pressure, you are attempting to raise capacity, then vessel sizes must be re-evaluated.

□ Are your <u>valves</u> suitable for low pressure differences encountered in elevated suction pressure conditions?

- You may need to make sure your evaporator pressure regulators (EPRs) have a sufficient pressure difference across them. Often these valves have a minimum required pressure drop for stable control. Aside from changing out the valves, there are other energy efficiency improvements like removing EPRs entirely.

<u>Compressor Sequencing</u>

Compressor sequencing is a no-capital cost way of reducing energy consumption related to part-load compressor inefficiency particularly with screw compressors. The following are general guidelines for compressor sequencing (Manske et al., 2002):

- If you use a reciprocating and a screw compressor, <u>utilize load following with reciprocating.</u>
    - Reciprocating compressors have much better part-load operating characteristics than screws.
- If you are using two screws to share the load, avoid allowing one or both compressors to operate below 50% load.
    - Screws should be sequenced such that they are running at or as close to part load as possible.
- If you use multiple reciprocating compressors to share the load, the load should be shared equally.
- Compressors with unequal capacities have different optimal sequencing than those with equal capacity.

- There are a few helpful examples in Section 6.3 of the Energy Efficiency Guidebook.

Operations

<u>Implement Load Shifting</u>

Review Utility Rate Structure
Utility rate structures reward energy consumption at off-peak hours of the day. Shifting refrigeration loads to off-peak times can result in a substantial savings. It is also important to analyze your rate plan to determine whether it is more important to have relatively flat energy consumption or to consume a bulk of the energy off-peak not worrying about peak demand. Typically, you will be charged based on your total energy consumption and also on your peak demand, so it is important to determine what peak loading scheme and energy demand profile will result in the largest savings.

Rate Plan A

Peak Power Usage Charge:
________$/kW

Energy Usage Charge:
________$/kWh

Rate Plan B

Peak Power Usage Charge:
________$/kW

Energy Usage Charge:
________$/kWh

Current Peak Power Usage: _______kW
Current Energy Usage: _______kWh
Ideal Rate Plan: Plan A / Plan B

Target Peak Power Usage: _______kW
Target Energy Usage: _______kWh
Ideal Rate Plan: Plan A / Plan B

Battery Charging Off-peak
Battery charging should be conducted during <u>off-peak hours outside of any refrigerated or conditioned space</u> if possible. This is an energy intensive process that would add significant heating loads on a refrigeration system and can increase peak power usage.

Improve Defrost Control Strategy

Defrost controlling can be a complex study, but there are a few relatively simple things that can be done to potentially reduce the cost of defrost and improve energy efficiency.

- □ Defrost off-peak so that the refrigerated space is pulled back down to normal conditions during times of low energy demand and reduced utility rates.

- □ If possible, stagger defrost of evaporators such that no two are in defrost at any time. This decreases pressure drop in defrost line headers.

- □ Reduce hot gas defrost pressure as low as possible to avoid heating evaporator coils and the refrigerated space unnecessarily. You may also find that defrost times do not need to be lengthened despite lower hot gas temperatures. Make sure that all of the ice is melted from the surface of the coils but also that defrost does not continue beyond this point.

- □ It may not be necessary to use hot gas as a defrost method. If the cooled space temperature is above 38°F to 40°F, consider allowing ice to melt using ambient air.

- □ Defrost system on a need basis rather than on a timed basis. Take some time to observe how long it takes for ice build-up on cooling coils to become detrimental to evaporator operation. Defrosting before ice on coils is a problem can severely penalize the energy efficiency of the system.

APPENDIX D

DAIRY BEST PRACTICES TEAM MEMBER CONTACT INFORMATION

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

Rich Hackner, P.E.
Agricultural Sector Program Manager
Wisconsin's Focus on Energy
GDS Associates
437 South Yellowstone, Suite 212
Madison, WI 53719
608-273-0182
Rich.hackner@gdsassociates.com

Doug Reindl, P.E.
Director
Industrial Refrigeration Center
UW-Madison
1415 Engineering Drive, Room 2350
Madison, WI 53706
608-262-6381
dreindl@wisc.edu

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

Preston Schutt
Director of Business Development
CleanTech Partners
2809 Fish Hatchery Road
Madison, WI 53713
608-441-6886
pschutt@cttinc.org

Tom Tucker, P.E.
Senior Consultant
EnVise LLC
203 South Paterson Street, Suite 200
Madison, WI 53703
608-663-3754
ttucker@envise.net

Doug Reinemann, Ph.D.
Biological Systems Engineering
College of Agriculture and Life Sciences
UW-Madison
Madison, WI 53706
608-262-0223
djreinem@wisc.edu

APPENDIX E

UNDERSTANDING YOUR UTILITY BILLS AND USE PATTERNS

Another useful step in a successful energy cost reduction program is understanding how the facility is billed for energy and what the energy use patterns are. It can also provide insight into reasonable savings estimates. The following is some of the relevant information contained on typical electricity and fuel bills. Your utility representative can help with others that might apply.

1. Meter #: The meter or account number represented by the bill. There may be multiple accounts and meters so be sure to consider all of them.

2. On-peak period: The period when utility electric generation (and use) is the highest. This is usually from 9 a.m. to 9 p.m. or 10 a.m. to 10 p.m. for most facilities, but can vary by utility and season.

3. Off-peak period: The period of time outside of the on-peak period.

4. Total on-peak consumption: The amount of electricity consumed by the facility during the on-peak period, usually expressed in kilowatt hours (kWh).

5. Total off-peak consumption: The amount of electricity consumed outside of the on-peak period, usually expressed in kilowatt hours (kWh).

6. On-peak demand: The maximum average demand that the facility reaches during the on-peak period. The peak demand averaging period is usually 15 minutes. This is why the short lived current spikes from equipment start-up have no real impact on the cost of electricity. Peak demand is usually expressed in kilowatts (kW) and is set once per month.

7. Off-peak demand: The off-peak demand is the average demand that the facility reaches during a 24-hour period. The off-peak demand often occurs during hours outside of the peak period. Off-peak demand is sometimes called customer demand, and is usually expressed in kilowatts (kW) and is set every 11 months.

8. Use charge: The rate charged for electricity consumed during the on-peak and off-peak periods. This is usually expressed in dollars per kWh ($/kWh).

9. Peak demand charge: The rate charged for the maximum average (billed) demand reached during the on-peak period. This is usually expressed in dollars per kW ($/kW).

10. Off-peak demand charge: Also called customer demand. The rate charged for the maximum average demand reached during the off-peak period. This is usually expressed in kilowatt hours ($/kW).

11. Facilities charge: Fixed monthly charge that has no relation to energy use.

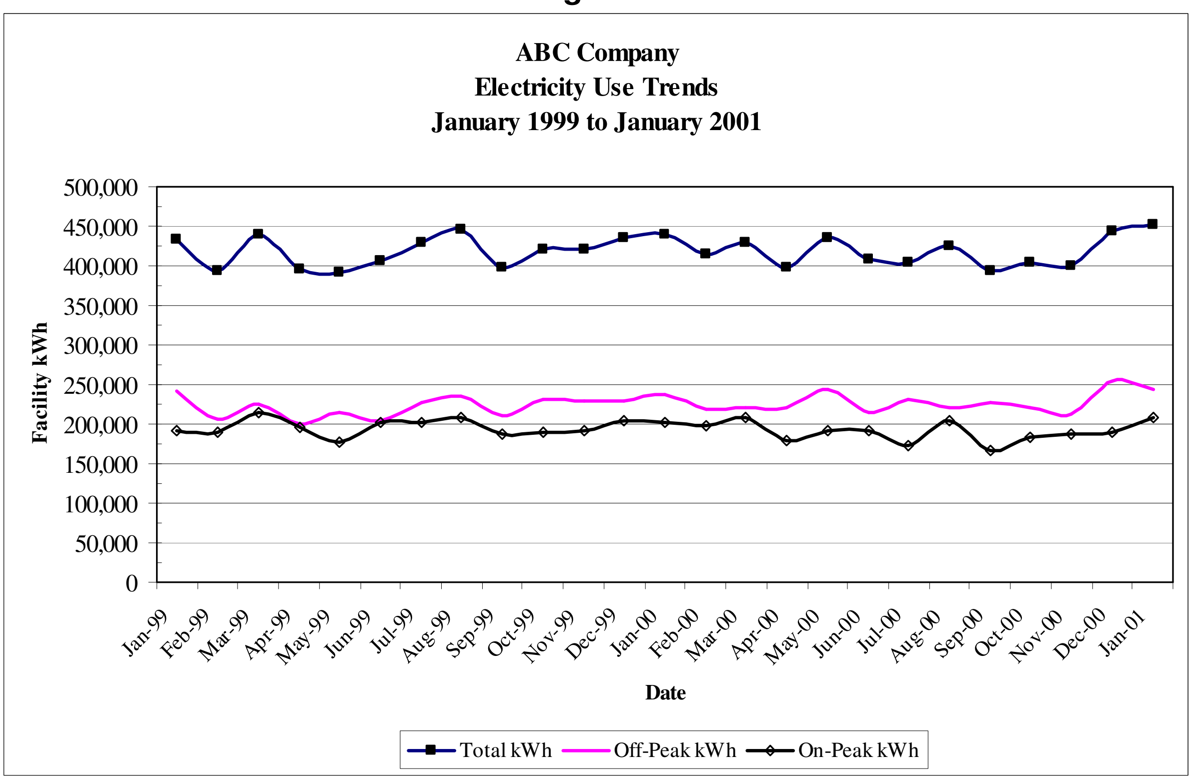
12. Fuel cost and transmission surcharge adjustments: Adjustments, either positive or negative, that reflect the increase or decrease in fuel costs, or maintenance on the generation, transmission and distribution system that delivers energy to the facility.

Fuel Bills
Fuel bills can be simple or complex depending on how a facility purchases fuel. Consult your utility representative for more information on billing cost structure. Gas fuels such as natural gas and propane are usually allocated in units of therms or millions of Btus (MMBtu) and fuel oil in terms of gallons. The quality of fuel oil can be easily converted to therms or MMBtu if the heating value of the fuel oil is known. Number 2 fuel-oil has a heating value of about 135,000 Btu per gallon and Number 6 fuel oil has a heating value of about 150,000 Btu per gallon.

Facility Use Patterns
Computer spreadsheets and other tools can provide visual insight into how a facility uses energy. This can be very helpful with identifying trends and/or changes in overall use. However, utility bills are often not a good means to look for expected savings from installed projects. The reason is that the savings can be masked by other changes in the facility. However, when used to evaluate trends, at least two years of data should be used. Trends could be related to production but are often related to weather as well.

Electricity Use
Figure 1 represents a summary of two years of electricity use data taken directly from utility bills. There is some variation in use (kWh) month-to-month. However, since there is no immediately discernable pattern, the variations are likely attributable to changes in production throughput. Note that the off-peak use is greater than the on-peak use. This may result from a strategic approach to reduce energy bills by operating as much as possible during the off-peak period. It may also be due to an increase in ventilation off-peak.

Figure 1



Interestingly, the efficiency of some equipment commonly used on ancillary process systems can decrease with decreasing load. This is a common issue with air compressors and chillers. It is possible that some of the variation in the curves could be resulting from a reduction in the efficiency of equipment as a result of partial loading.

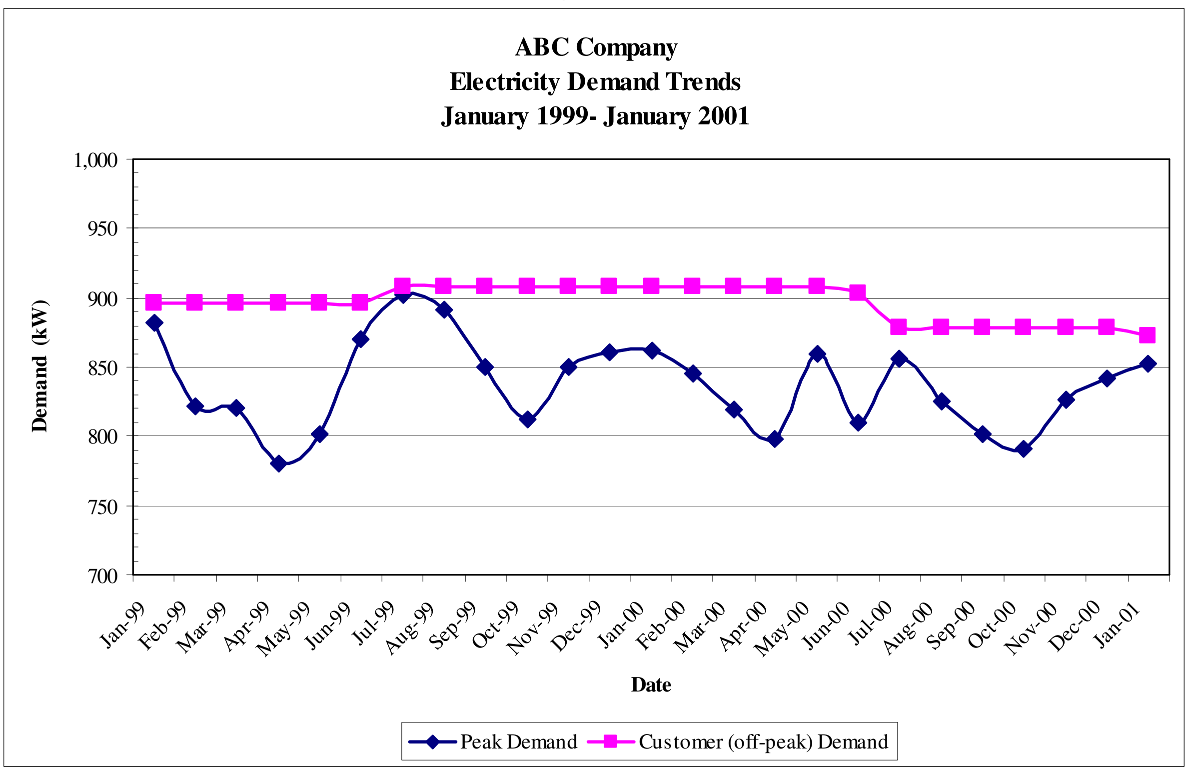
When the summer load increases such as from the use of air conditioning, there will be a more prevalent increasing trend over the summer months, with increases starting in May/June to September.

Electricity Demand

Figure 2 represents a summary of two years of billed demand data taken from the same utility bills as the data in Figure 1. There is much less variation in the off-peak demand curve than the peak demand curve because the peak demand is reset each month. Off-peak demand usually goes with the highest value in an 11-month period. For example, the off-peak demand from July 1999 to June 2000 is 908 kW because that was the highest point reached in the 11-month period. However, the off-peak demand dropped at the end of the 11-month period in July 2000 to 902 kW.

The peak demand curve shows variation that could be due to production related issues or to weather. If weather is an issue it likely does not play a significant role, as evident from curves in Figure 1. However, more data could easily be plotted to look for potential weather trends over a longer period.

Figure 2



Natural Gas Use

Figure 3 on the next page represents a summary of two years of natural gas data. The variation in fuel use between summer and winter is evident from the cyclic nature of the curve. The months of low use occur during the summer. The summer monthly totals reveal that the base-load use related to production processes and other "typical" uses of natural gas (such water heating) is about 5,000 therms per month. The total gas use for 1999 is about 211,276 therms and for 2000 about 207,571 therms. This information allows for an estimate of annual process use and the use for winter heating.

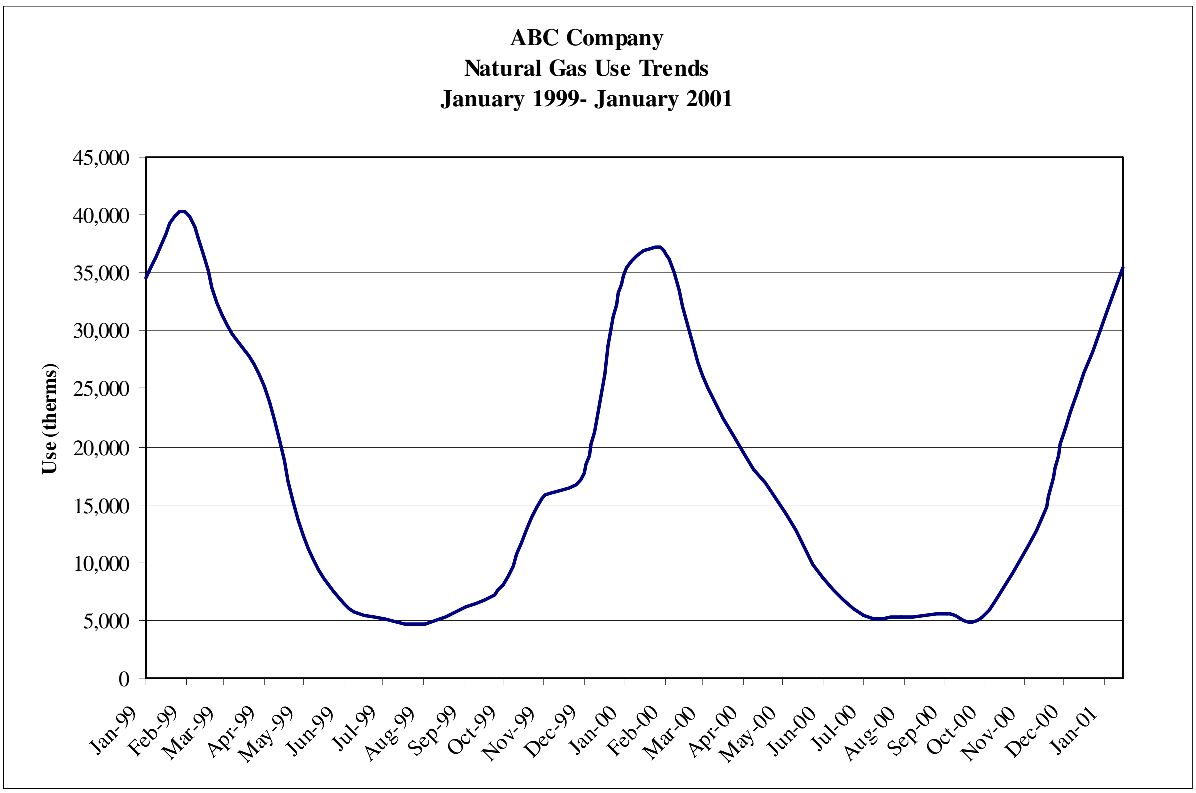
Annual process (base-load) use is:
5,000 therms/month * 12 months/year = 60,000 therms/year

Using this information, the winter heating load is:
211,276 therms/year – 60,000 therms/year = 151,276 therms/year

At a natural gas price of $0.80/therm, the process gas cost is:
60,000 therms/year * $0.80/therm = $48,000/year

Likewise, the winter heating gas cost is:
151,276 therms/year * $0.80/therm = $121,020/year

Figure 3



This information can then be used with rules of thumb or other facility information to determine if there is an opportunity to reduce winter heating costs. In this case there was a significant low-cost opportunity because loading dock doors were being left open a significant portion of the day. If the doors were being left open to improve ventilation, radiant heating could be a potential option to reduce the cost of heating air (radiant heat heats objects). Other options may also be available.

APPENDIX F

ADDITIONAL RESOURCES FOR THE DAIRY PROCESSING INDUSTRY

WISCONSIN'S 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 highlights. 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 and ask for the industrial team.
- Incentives are available for new projects, those that have not 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.

CLEANTECH PARTNERS (Formerly - CENTER FOR TECHNOLOGY TRANSFER, INC.) : www.cttinc.org - MISSION: The mission of the CleanTech Partners, Inc. (CTP) is to help companies overcome barriers that restrict the commercialization of energy efficient technologies in Wisconsin.

CTP is unique due to its ability to assist in the commercialization of energy efficient technologies by providing capital in the form of loans or equity to companies not typically served by traditional financial resources. This capital, coupled with CTP's technical, business and financial expertise can help bridge the gaps preventing the adoption and commercialization of new technology.

CTP's technology investment funds are aimed at companies with technologies specific to the forest products (paper), metal casting, food processing, printing and plastics industries. CTP 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 CTP. Examples of specific CTP programs include:

- **Funding for New Energy Technologies:** To reduce energy usage on a long term basis, CTP can provide up to $350,000 to fund demonstrations of new emerging technologies and to commercialize new energy efficiency technologies. The funds can be provided to the company developing the technology either in the form of equity or loans. The funds can be leveraged with other financing and a variety of payback models are available, including shared savings.

- **Green Tier Assistance:** Green Tier is an innovative, voluntary program that allows the Wisconsin DNR to create incentives for companies to "go beyond" standard environmental compliance. Through a grant from the US Department of Energy, and in cooperation with the

DNR, CTP provides free assistance to companies negotiating Green Tier contracts that will deliver superior energy and environmental results.

INDUSTRIAL REFRIGERATION CONSORTIUM: A collaborative effort between the University of Wisconsin Madison and industry whose goal is to improve the safety, efficiency, and productivity of industrial refrigeration systems and technologies. This goal is realized by conducting applied research, delivering knowledge transfer, and providing technical assistance. Although its efforts are focused on industrial refrigeration systems that utilize anhydrous ammonia, IRC also works with systems that use other refrigerants. The IRC offers a unique combination of complementary resources that include academic qualifications, technical expertise, and practical experience. We provide objective information that is not biased by an affiliation with any particular organization. See the following for more information: www.irc.wisc.edu/

GROW WISCONSIN DAIRY TEAM: Created to increase support for Wisconsin's growing dairy industry, the Grow Wisconsin Dairy Team is a joint venture between the Department of Agriculture, Trade and Consumer Protection, Department of Commerce, UW Center for Dairy Profitability, UW Extension and Wisconsin Technical Colleges. Grants of up to $200,000 may be awarded to commodity processors in order to improve Wisconsin's dairy competitiveness by implementing major initiatives to add value or cut costs in their businesses. Projects involving collaboration between processors and dairy farmers that promote supply chain value are encouraged. See the following for dairy processor grant information: www.growwisconsindairy.org/apply_grants/dairy_plant_processor/commodity_innovation.asp

The Center for Industrial Research and Service (CIRAS): Provides education, research and technical assistance to Iowa industry through partnerships with Iowa's universities and community colleges, government agencies and professional associations. Assistance is supported in part by the DoC/NIST Manufacturing Extension Partnership, the DoD Procurement Technical Assistance Program and the DoC/EDA University Center Program. For an on-line version of their publication, "Energy-Related Best Practices: A Sourcebook for the Food Industry" refer to: http://www.ciras.iastate.edu/publications/EnergyBP-FoodIndustry/

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 : *www.oit.doe.gov/bestspractices/library.shtml*
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/*
- Case Studies – Profiles of companies and organizations that have made energy savings improvements and how they did it.

- 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.
- Energy matters – Best Practices' award-winning quarterly newsletter carries articles from industry experts, tips for performance optimization, case studies and news on current program activities.
- Industrial Technology Program (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.
- Library links – Links to ITP Allied Partners and industry association colleagues, many have very complete energy efficiency library collections.

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 Website 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.

NORTHWEST FOOD PROCESSORS ASSOCIATION - The Energy Portal is your resource for energy efficiency information specifically tailored to the food processing industry. Within these pages you will find the most comprehensive collection of energy-specific web resources, electronic documents, downloadable materials and links to additional information available to the food processing industry. This information has been compiled by the Food Industry Resource Efficiency team (FIRE), a partnership between the Northwest Food Processors Association (NWFPA) and the California League of Food Processors (CLFP) in collaboration with a number of public and private sector partners. http://www.nwfpa.org/eweb/?site=Energy&design=no

NATURAL RESOURCES CANADA (NRCAN) has been promoting the more efficient use of energy in the Canadian economy for a number of years. The Canadian dairy sector, through its involvement in the Canadian Industry Program for Energy Conservation (CIPEC), has participated actively in these energy initiatives. The National Dairy Council of Canada (NDCC) coordinated this study and NRCAN provided the funding. The study can be found at the following Website:
http://strategis.ic.gc.ca/epic/internet/inggeb-aceges.nsf/en/h_ge00108e.html

OTHER

Energy Center of Wisconsin. See http://www.ecw.org

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

Natural Resources Canada has a Guide to Energy Efficiency Opportunities in the Dairy Processing Industry. See http://oee.nrcan.gc.ca/infosource/pdfs/M27-01-827E.pdf

PUBLICATIONS

Practical Energy Management, Tools for Creating and Implementing an Energy Management Program, 2003, Focus on Energy. Contact the Focus on Energy Industrial Program at: 800-762-7077

Wisconsin Department of Agriculture, Trade and Consumer Protection, *"Got Moola? Where to Go for Business Assistance in Wisconsin"*
http://www.datcp.state.wi.us/mktg/business/business_resources/pdf/Wisconsin_Business_Resources.pdf

APPENDIX G - ACKNOWLEDGEMENTS

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

Nick George
Midwest Food Processors Association
P.O. Box 1297
Madison, WI 53701-1297
Phone: 608-255-9946
info@mwfpa.org

John Umhoefer
Wisconsin Cheese Makers Association
8030 Excelsior Drive, Suite 305
Madison, WI 53717-1950
Phone: 608-828-4550
jumhoefer@wischeesemakersassn.org

Jim Cisler
GROW Wisconsin Dairy Team
Wisconsin Department of Agriculture, Trade and Consumer Protection
2811 Agriculture Drive
Madison, WI 53703
Phone: 608-224-5137
James.Cisler@datcp.state.wi.us

Alex Kisslinger
CIRAS Energy Specialist.
2272 Howe Hall, Suite 2620,
Ames, Iowa 50011
Phone: 515-294-1588
alexkr@iastate.edu

Michael E. Rohde, P.E.
Rohde Brothers, Inc.
W5745 Woodchuck Lane
Plymouth, WI 53073-0409
Phone: 920-893-5905
rohde@rohdebros.com