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Author
Masanet, Eric

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Energy Efficiency Improvement and Cost Saving Opportunities for the Baking Industry

An ENERGY STAR® Guide for Plant and Energy Managers

Eric Masanet, Peter Therkelsen, and Ernst Worrell

Environmental Energy Technologies Division

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Abstract

The U.S. baking industry—defined in this Energy Guide as facilities engaged in the manufacture of commercial bakery products such as breads, rolls, frozen cakes, pies, pastries, and cookies and crackers—consumes over $800 million worth of purchased fuels and electricity per year. Energy efficiency improvement is an important way to reduce these costs and to increase predictable earnings, especially in times of high energy price volatility. There are a variety of opportunities available at individual plants to reduce energy consumption in a cost-effective manner. This Energy Guide discusses energy efficiency practices and energy-efficient technologies that can be implemented at the component, process, facility, and organizational levels. Many measure descriptions include expected savings in energy and energy-related costs, based on case study data from real-world applications in food processing facilities and related industries worldwide. Typical measure payback periods and references to further information in the technical literature are also provided, when available. A summary of basic, proven measures for improving plant-level water efficiency is also provided. The information in this Energy Guide is intended to help energy and plant managers in the U.S. baking industry reduce energy and water consumption in a cost-effective manner while maintaining the quality of products manufactured. Further research on the economics of all measures—as well as on their applicability to different production practices—is needed to assess their cost effectiveness at individual plants.

Table of Contents

Energy Efficiency: A Commitment to Good Business

Finding effective ways to manage energy helps your company keep costs down and stay competitive. Did you know a well-run energy program can reduce energy costs by 3% to 10% annually? An added bonus is that improving energy efficiency reduces waste and emissions - things that cost your company money!

Organizations often differ in energy performance, even when they belong to the same industry, operate under the same market conditions, and use the same equipment. Why the big performance gap?

Research shows that high performers adopt a structured approach to energy management. They establish policies and procedures for long-term results, have senior management's support, allocate staff and resources, establish goals, develop management structures that empower staff to address energy efficiency issues directly, and adopt a philosophy of continuous improvement.

This *Energy Guide* provides the information you need to establish a structure that will work for your company and identify cost-effective practices and technologies to reduce energy use throughout your company's operations.

1 Reducing Energy Use to Meet Energy, Cost, and Environmental Targets

Volatile energy markets, growing competition, and worldwide regulation of greenhouse gas (GHG) emissions are influencing many U.S. manufacturers to consider energy management as an untapped opportunity. They are finding that production costs can be reduced without negatively affecting the yield and quality of products while reducing energy consumption and costs.

Energy efficiency, which includes sound plant-wide energy management practices combined with energy-efficient technologies, offers additional benefits, such as product quality improvement, increased production, and increased process efficiency—all of which can lead to productivity gains. As a component of a company's overall environmental strategy, energy efficiency improvements often lead to reductions in GHG emissions and other important air pollutants. Investments in energy efficiency are a sound and key business strategy in today's manufacturing environment.

This Energy Guide provides an overview of available measures for energy efficiency in the commercial baking industry. Specific energy consumption can vary widely among different plants, and depends on the types of product manufactured and the condition of the equipment. This Energy Guide is concerned with the most important systems, equipment, processes and practices that account for the bulk of energy consumption in the baking industry.

This Energy Guide is offered as part of the ENERGY STAR® program. ENERGY STAR is a voluntary partnership program of the U.S. Environmental Protection Agency (EPA) that helps U.S. industry improve its competitiveness through increased energy efficiency and reduced environmental impact. Through ENERGY STAR, EPA stresses the need for strategic corporate energy management and provides a host of energy management tools and strategies to help companies build such programs. For further information on ENERGY STAR and its tools, visit the ENERGY STAR website (U.S. EPA 2012e).

The Energy Guide is organized into the following sections:

- Section 2 briefly describes the U.S. baking industry and its major energy uses.
- Section 3 outlines steps to follow in designing an effective energy management program.
- Sections 4 - 6 discuss energy savings opportunities in major plant systems and operations. All efficiency measures are technically proven, commercially available, and have reasonable investment costs.
- Section 7 provides a brief overview of basic water efficiency measures.
- Section 8 provides a summary.
- Appendices A-D contain numerous resources for identifying and implementing efficiency measures in practice.

2 Commercial Baking and Energy Use

This section briefly describes the basic processes and typical energy consumption in commercial bakery plants. Energy use and intensity may vary from plant to plant.

In their simplest form, most bakery products (bread, rolls, cookies, crackers) have similar ingredients and stages of production. Bakery product ingredients may vary but typically consist predominantly of flour, water, and salt. Minor ingredients are used to change attributes such as volume, crumb softness, grain uniformity, silkiness of texture, crust color, flavor and aroma, softness retention, shelf life, and nutrient value (U.S. EPA 1992). Leavened products contain yeast that is developed in the production process in various ways depending upon the production method and recipe. Products that require dairy ingredients require special sanitation and practices.

Common production stages include: mixing, shaping, baking, cooling, and packaging (Sikirica et al. 2003). Certain products require additional production steps. Yeast based products require time for yeast to develop necessitating fermentation and proofing stages. Some bread and roll products are sliced before packaging. Additionally, some products require finishing work, adding decorative items, coatings, etc, after baking and cooling. Frozen products, such as some pies, are frozen in lieu of being cooled to room temperature (Sikirica et al. 2003).

Today, modern large commercial bakeries use highly automated processes during production. When operating at full capacity, a single large bread bakery may produce up to 300,000 pounds of over 100 different varieties of bread and other bakery products per day. All physical mixing and blending of ingredients, as well as the working and dividing of the dough, is performed mechanically. Most dough batches are conveyed through each step of the process, from the initial dividing through the final slicing and bagging, with minimal handling (U.S. EPA1992).

Commercial bakeries are categorized under the North American Industry Classification System (NAICS) code system as 311812 (commercial bakeries), 311813 (frozen cakes, pies and other pastries), and 311821 (cookies and crackers).

Table 1 summarizes key economic and energy purchase data for these three segments of the U.S. baking industry. Total employment in 2010 exceeded 230,000 and total value of product shipment exceeded $53 billion—numbers that underscore the significant contributions made to both U.S. employment and economic output. Over $800 million was spent on purchased fuels and electricity in 2010. While energy costs represented only 4% of total cost of materials, the sheer amount spent on purchased fuels and electricity at U.S. commercial bakeries suggests that energy efficiency can play a critical role in reducing operating costs nationwide.

Table 1. Summary of economic and energy purchase data, 2010

NAICS	Description	Employees	Total cost of materials ($1,000)	Cost of purchased fuels ($1,000)	Cost of purchased electricity ($1,000)	Quantity of electricity purchased (1,000 kWh)	Value of products shipments ($1,000)
31181	Bread and bakery product manufacturing	187,309	12,824,198	224,423	383,916	4,597,092	33,137,919
31182	Cookie, cracker, and pasta manufacturing	45,453	8,762,415	94,786	168,703	2,456,380	20,281,586
Total		232,762	21,586,613	319,209	552,619	7,053,472	53,419,505

Source:(United States Census Bureau 2011)

Figure 1 shows generic production process diagrams for each of the three NAICS codes addressed in this report. NAICS code 311812 (commercial bakeries) is divided into two parts, breads and roll as well as cakes and pies. As previously described, the figures show that most bakery produces are produced with the same core processes: mixing, shaping or forming, baking, cooling or freezing, and packaging. Process steps specific to one of the different generic product types are also seen: fermentation, proofing, slicing, pan washing, and shortening storage.

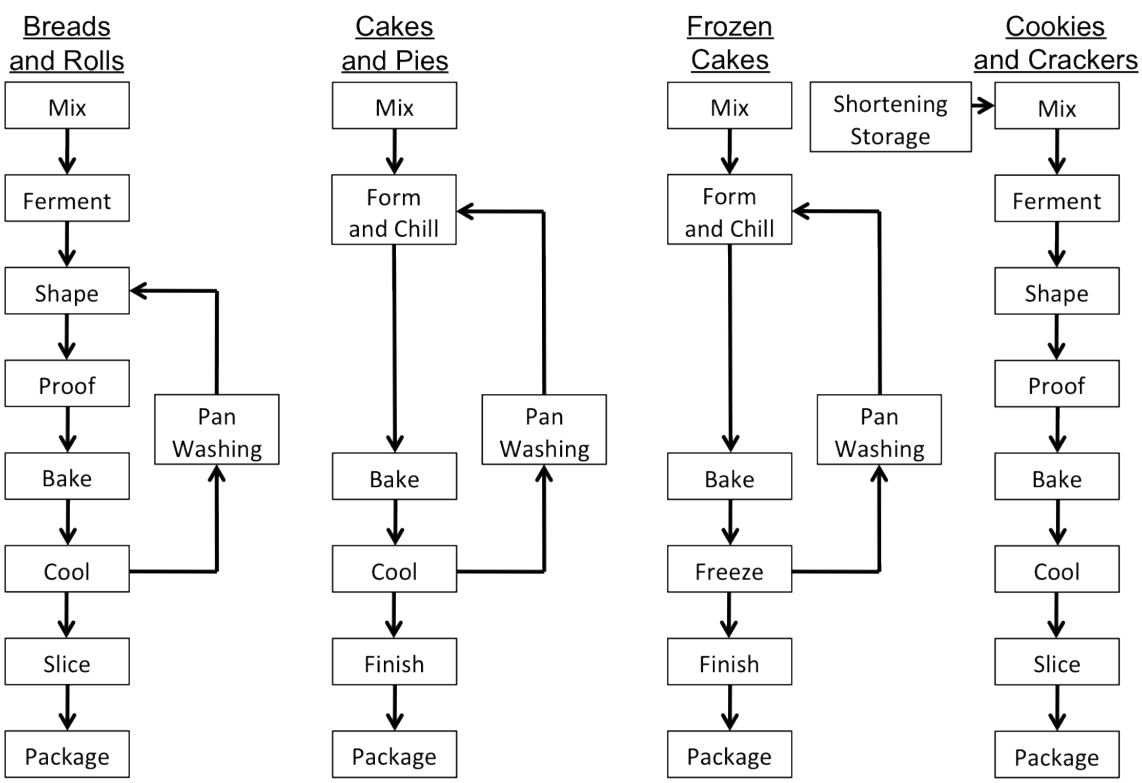

Figure 1. Bakery product production processes

Source: Adapted from (Brown 1996, Sikirica et al. 2003)

Tables 3 through 6 provide generic process energy requirements for each of the aggregated product types in Figure 1. The values listed are not meant to be absolute and are only representative of the energy required to produce a typical product. Specific product-to-product and plant-to-plant variations will occur. Each table breaks down the generic energy requirements by energy type – that is, the steam, fuel (natural gas, diesel, other oils), refrigeration (typically electricity), and electricity required for the process step – in British thermal units (BTUs) per unit of production. Additionally, each table lists the relative percentage of energy required for a given process step as a function of the total energy requirement.

Table 2 lists specific energy requirements measured by a U.S. roll manufacturer (Northeat Foods 2012). Values in table 2 are listed per pound of dough produced, unlike tables 3-6, which list energy values in terms of energy per pound of production. Due to this difference direct comparisons between energy values cannot be made but the relative proportion of energy used in different process stages can be examined. Comparison of tables 2 and 3 highlights the large variation of energy consumption between different process stages between various plants.

Energy use is most concentrated in either the baking or freezing process. For non-frozen products, baking is the largest energy consumer ranging between 26 to 78% of total energy. Only in the case of frozen products is baking not the largest portion of energy. Baking represents 78% of the energy requirement for cookies and crackers, which are products produced with no need to wash pans or provide a fermentation and proofing period. Bread and rolls as well as cookies and crackers, which are products that require significant baking times, require more energy per unit of production than frozen and non-frozen cakes.

In the case of frozen products, the freezing process consumes the most energy. For example, this characteristic is explicitly seen when comparing the energy requirement of non-frozen and frozen cakes in Tables 4 and 5.

In addition to the baking and freezing processes, the other stages of production consume large enough amounts of energy as to warrant investigating related energy efficiency measures. This guide details energy saving opportunities for all of these processes as well as cross cutting energy using equipment such as motors, pumps, HVAC systems, lighting, and boilers. These systems can account for more than half of the energy consumed by a bakery and can be simpler and more affordable to manage that process specific equipment (Frank 2009, McMullen 2010c).

Table 2. Measured energy requirement per pound of dough at a bakery producing rolls

BTU/pound of dough	Steam	Fuel	Refrigeration	Other Electricity	Percent of Total
Mix	0.0	0.0	66.0	42.4	21.0%
Ferment	8.5	0.0	0.0	2.0	2.0%
Shape	0.0	0.0	0.0	37.9	7.5%
Proof	0.0	0.0	0.0	6.8	25.5%
Bake	125.0	205.2	0.0	2.7	40.0%
Cool	0.0	0.0	0.0	11.1	2.0%
Slice	0.0	0.0	0.0	2.1	0.5%
Package	0.0	0.0	0.0	7.0	1.5%
Total	133.5	205.2	66.0	112.0	516.7

Source: (Northeat Foods 2012)

Table 3. Bread and Rolls (311812, commercial bakeries) energy requirement per pound of production

BTU/pound of product	Steam	Fuel	Refrigeration	Other Electricity	Percent of Total
Mix	0.0	0.0	0.0	37.4	1%
Ferment	287.5	0.0	0.0	0.0	11%
Shape	0.0	0.0	0.0	100.3	4%
Proof	159.7	0.0	0.0	0.0	6%
Bake	134.9	1533.3	0.0	82.3	66%
Cool	0.0	0.0	0.0	120.8	5%
Slice	0.0	0.0	0.0	56.3	2%
Package	0.0	0.0	0.0	120.8	5%
Total	582.1	1533.3	0.0	517.6	2633.0

Source: Adapted from (Sikirica et al. 2003)

Table 4. Cakes (311812, commercial bakeries) energy requirement per pound of product

BTU/pound of product	Steam	Fuel	Refrigeration	Other Electricity	Percent of Total
Mix	0.0	0.0	0.0	80.4	6%
Form and Chill	75.7	0.0	0.0	0.0	6%
Bake	0.0	389.5	0.0	13.4	31%
Cool	0.0	0.0	0.0	0.0	0%
Pan Washing	295.8	0.0	0.0	56.3	27%
Finish	0.0	0.0	0.0	80.4	6%
Package	0.0	0.0	0.0	80.4	6%
Total	582.1	389.5	0.0	311.0	1282.6

Source: Adapted from (Sikirica et al. 2003)

Table 5. Frozen cakes, pies, and other pastries (311813) energy requirement per pound of product

BTU/pound of product	Steam	Fuel	Refrigeration	Other Electricity	Percent of Total
Mix	0.0	0.0	0.0	114.5	5%
Form and Chill	108.0	0.0	0.0	0.0	5%
Bake	0.0	555.6	0.0	19.1	26%
Freeze	0.0	0.0	722.1	0.0	32%
Pan Washing	422.0	0.0	0.0	80.2	22%
Finish	0.0	0.0	0.0	114.5	5%
Package	0.0	0.0	0.0	114.5	5%
Total	530.0	555.6	722.1	442.8	1750.5

Source: Adapted from (Sikirica et al. 2003)

Table 6. Cookies and crackers (311821) energy required per pound of product

BTU/pound of product	Steam	Fuel	Refrigeration	Other Electricity	Percent of Total
Shortening storage	0.0	9.0	0.0	0.0	0%
Mix	0.0	0.0	0.0	48.53	2%
Shape	0.0	0.0	0.0	130.20	6%
Bake	0.0	1791.3	0.0	0.0	78%
Cool	0.0	0.0	0.0	156.84	7%
Package	0.0	0.0	0.0	156.84	7%
Total	0.0	1800.2	0.0	492.4	2292.6

Source: Adapted from (Sikirica et al. 2003)

3 General Practices for Managing Your Energy Use

All industrial plants should make energy management a priority, and take action by implementing an organization-wide energy management program. Doing so is one of the most successful and cost-effective ways to save energy. The ENERGY STAR program offers a variety of tools and resources to assist companies in developing strategic energy management approaches.

ENERGY STAR® Energy Management Resources

The U.S. Environmental Protection Agency's (EPA) ENERGY STAR® Guideline for Energy Management (EPA, 2012a) provide a management structure for organizations to follow in developing a strategy for achieving sustained performance.

Another ENERGY STAR guide, Teaming Up to Save Energy (EPA, 2012b), outlines how to form an energy team. By establishing a program, forming an energy team, increasing employee awareness, monitoring progress, and incorporating feedback into the process, companies can reduce their energy use and emissions, and potentially save money.

3.1.1 Effective Principles for Energy Savings

Companies that apply a few basic principles to energy management can achieve substantial savings. These principles can be applied by any company, regardless of size, that is committed to reducing energy use:

- **Make it a priority**
  Saving energy starts by making energy management a priority. Everyone in the company must recognize that reducing energy use is an important business objective and incorporate it into their decision making.

- **Commit to energy savings**
  Every level of the organization, from senior management on down, must commit to continuous energy efficiency improvement.

- **Assign responsibility**
  If you want to save energy, designate someone to be responsible for achieving a savings goal. Initially, this might be a designated "energy champion," but over time the responsibility can be expanded across the company. An energy team is a practical way to share the responsibility with roles assigned to each member of the team.

- **Look beyond first cost**
  With energy efficiency, you get what you pay for. It is critical to recognize that energy efficient equipment and products may cost the company more initially but that the lasting savings gained from their use will save more money over time.

- **Make energy management a continuous process**

Successful energy management involves more than just installing a few energy-efficient technologies. It involves establishing a committed company-wide program to manage energy continuously as a function of your business. It's an ongoing process that involves:

- understanding your energy use,
- setting goals,
- implementing good operational and maintenance practices,
- making behavioral changes,
- tracking and benchmarking energy use, and
- involving every employee.

ENERGY STAR works with leading industrial manufacturers to identify the fundamental aspects of effective energy management programs (EPA, 2012e). Figure 2 depicts the major steps of an effective energy management system as identified by ENERGY STAR. The same principles and concepts are incorporated into the recently published international standard for energy management systems known as ISO 50001.

Throughout the process, personnel at all levels should be aware of energy use and efficiency goals. Staff should be trained in both skills and general approaches to energy efficiency in day-to-day practices (examples of simple tasks employees can do are outlined in Appendix A). In addition, regularly evaluate and communicate performance results to all personnel, and reward and recognize high achievements. Evaluating action plan progress requires a regular review of both energy use data and the activities carried out as part of the plan. A quick assessment of an organization's efforts to manage energy can be made by comparing its current energy management program against the ENERGY STAR Energy Program Assessment Matrix (EPA, 2012c) provided in Appendix B.

To help companies assess the energy performance of their plants, ENERGY STAR develops plant level energy benchmarking tools called Energy Performance Indicators (EPIs). ENERGY STAR EPIs are sector-specific benchmarking tools that compare a plant's energy performance to the rest of the industry. Plant energy performance is scored on scale of 1 to 100 with the benchmark for efficiency set at 75. EPI have been published for Cookie and Cracker Bakeries and are planned for Commercial Bakeries that produce bread and rolls (EPA, 2012d). ENERGY STAR EPIs provide an evaluation of how efficiently the whole plant is performing as system. Plants that receive low energy performance scores should be prioritized for assessments to identify area for energy saving opportunities. Plants that score high should be reviewed to identify potential best practices and strategies that can be shared across the organization.

Four key elements contribute to the process of energy management: plant energy assessments, energy teams, employee awareness, and energy monitoring. These elements are discussed below.

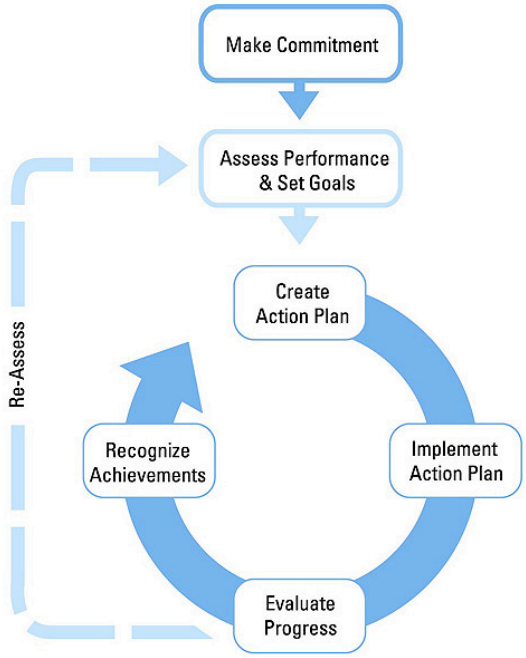

Figure 2. Elements of strategic energy management, ENERGY STAR Guidelines for Energy Management

3.1.2 Plant Energy Assessments

Plant energy assessments determine where and how much energy is consumed in a plant and identify steps to improve energy efficiency. Use this Energy Guide to inform the scope and focus of an assessment in a baking plant. Whether the assessment focuses on a whole site or on specific systems or processes, opportunities to save significant amounts of energy and money will be identified.

Assessments can be conducted by company staff, the local utility company, professional energy engineers, or regional assistance centers.

- **Staff Teams**
  If company staff perform the plant assessment, it is effective to team up staff from various departments across the facility or company. The combined team approach brings together rich experience and knowledge on the plant and processes used. Such efforts can be successfully replicated at all sizes of facilities. The U.S. Department of Energy (U.S. DOE) also offers various tools to help with assessments (see Appendix C).

- **Utility Programs**
  Local utility companies work with their industrial clients to achieve energy savings in both existing facilities and in the design of new facilities. Check with your local utility company to see what assistance they can provide. Sometimes, utilities offer specific programs for improving plant systems such as lighting or motors.

- **Regional Assessment Centers**

  Regional Industrial Assessment Centers (IACs) (US. DOE 2012b) have been established at 24 universities across the United States. Supported by the U.S. DOE, IACs (see Assessment and Technical Assistance in Appendix C) are designed to help small- and medium-sized enterprises. Universities participate in the program and offer free assessments, performed by students and university staff, to local companies.

Case study: Plant energy assessment reveals large savings potentials

A U.S. bread plant with annual energy costs of approximately $820,000 per year conducted a plant energy audit, which identified a number of cost-effective energy efficiency opportunities that could reduce the plant's annual energy bill by 7%. Opportunities included improved motor controls, reductions in compressed air usage, and occupancy sensors. The total investment costs of around $56,000 would be paid back in one year through energy savings alone (BASE 2012).

3.1.3 Energy Teams

Establishing an energy team solidifies a company's commitment to improve energy efficiency. The team is responsible for planning, implementing, benchmarking, monitoring, and evaluating the organization's energy management program. However, duties can also include delivering training, communicating results, and providing employee recognition (U.S. EPA 2006).

Forming the Team

When forming an energy team:

- establish the structure,
- name team members, and
- specify roles and responsibilities.

Any size company can create an energy team

Team size and time commitment depends on the size and resources of the facility, its energy use, and the complexity of the key energy-consuming processes. Generally, in large facilities this will be a more substantial effort than in small facilities, where the team is likely to be a part-time effort of a few staff members.

Energy management needs to be valued from the top down as part of the organization's core business. Ideally the energy team leader will be someone at the corporate level who is empowered with support from senior-level management. The team should include members from each key energy-using process within the company. Ensure adequate funding, preferably as a line item in the normal budget cycle, as opposed to a special project.

Prior to the energy team's launch, hold a series of team strategy meetings to consider key goals, as well as potential pilot projects whose savings could be showcased at the program's kickoff. This Energy Guide should be consulted for project ideas as it identifies energy efficiency options in bakery operations. Another important ENERGY STAR tool is the facility assessment matrix (U.S. EPA 2012a) (see Appendix B), which can help the team identify missing energy management practices in the plant. The team should then perform a facility energy assessment (see above) to identify opportunities for energy efficiency improvements. As part of the facility assessment, the energy team should also look for best practices in action to help highlight successful strategies. Appendix D provides a checklist of key steps for forming, operating, and sustaining an effective energy management team.

Tracking and Communicating Results

A key energy team function is to track and communicate progress, and to transfer knowledge gained through the assessments across an organization. Successful energy teams use best practice databases, facility benchmarking tools, intranet sites, performance tracking scorecards, and case studies of successful projects to help manage information.

A best practices database may be as simple as documenting energy saving best practices and case studies of successful projects identified by the team. It is important to have them accessible to all energy, plant, and shift managers. This can be done through a dedicated intranet site for the company or through other communication tools.

Benchmarking is a method for assessing energy performance by comparing (energy) performance over time and between peer facilities in a consistent manner. Benchmarking can be very helpful to track performance of a plant and to identify opportunities for improvement (e.g. as energy intensity increases in a given period, or is higher than that of facilities with a similar mix of products). As noted earlier, the ENERGY STAR program offers various industrial benchmarking tools (U.S. EPA 2012f). Regular benchmarking provides the means for monitoring plant performance over time.

To sustain the savings and build momentum for continuous energy improvement, results and lessons learned must be communicated regularly to managers and employees, and a recognition and rewards program should be established. Seeking recognition from external organizations can help to further increase awareness of the value of energy management. The ENERGY STAR program offers several forms for recognition for manufacturing plants:

- ENERGY STAR Partner of the Year for Excellence in Energy Management – Awarded to companies with world class energy management programs that achieve significant energy savings.
- ENERGY STAR Certification – Awarded to manufacturing plants where the EPA has released a plant Energy Performance Indicator (EPI) that scores energy performance.
- ENERGY STAR Challenge for Industry Achiever – Awarded to manufacturing plants that achieve a 10% or greater reduction in energy intensity within five years of registering a baseline energy intensity with ENERGY STAR.

3.1.4 Employee Awareness

Energy management involves more than just changing out old, inefficient equipment. It involves changing a company's culture as well. Employees must be trained in how to follow new processes or operate new energy-efficient equipment.

Educated, empowered employees identify and achieve energy savings

Engage employees and operators in energy assessments, projects, and the program—especially in day-to-day decisions. An effective energy awareness campaign:

- educates employees and operators about how their work practices affect the company, energy use, costs, and the environment,
- informs employees on how they can manage energy in their day-to-day responsibilities, and
- reminds employees about the company's energy goals.

To implement an effective energy awareness campaign, you must raise the level of:

- employee energy awareness,
- behavioral change, and
- active employee involvement.

Identify your audience and message to help you design a targeted awareness program. Periodically, review and evaluate the awareness campaign to ensure it is generating the desired results and refresh it frequently.

A wide array of activities can be included in an awareness campaign. ENERGY STAR has encountered a number of successful corporate approaches, including placement of stickers at light switches (Kodak), distribution of energy efficient light bulbs to personnel (ArcelorMittal), handing out leaflets on home energy savings (Toyota), and hosting energy training sessions for employees and giving access to home audit measurement devices (Titan America). Additional ideas include hanging posters in conspicuous locations and having information stands at employee events or in employee break rooms.

Assistance with Employee Awareness Programs. Many organizations run large energy awareness campaigns, often in collaboration with the ENERGY STAR program or the Federal Energy Management Program (FEMP). These programs offer advice on how to run an energy efficiency campaign and provide materials (such as posters) that can be tailored to your company (U.S. DOE2012a, U.S. EPA2012b, U.S. EPA2012c).

3.1.5 Energy Monitoring Systems

Sustaining energy savings over time requires continuous energy management. You cannot manage what you do not measure. Every company needs to compile, track, and benchmark energy data. Reliable energy data helps a company manage energy and interpret energy efficiency trends in operations over time.

Data on energy use can be found in utility bills, fuel purchase receipts, or from self-installed meters. Ideally, individual departments or processes should be sub-metered. Good energy data systems alert the energy team to problem areas. When changes in energy use occur, opportunities for corrective action and improvement can be identified by the energy team immediately.

Reading self-installed or utility-owned meters daily or weekly enables collection of more frequently data than is possible with utility billing data. This increased frequency improves the ability to quickly address changes in energy use and intensity. Sub-metering different production departments provides improved metrics but also enables quick pinpointing of areas where energy problems may occur. An added bonus is that installed meters supply the information needed to calculate energy and cost savings from implemented energy management activities.

Except for installation of sub-meters, an energy monitoring system requires little or no upfront capital and may result in immediate savings. Energy monitoring systems incorporate sub-meters at key places in a plant where energy may be strategically managed. Management of data from the meters is best handled by a data management tool; a simple spreadsheet may be sufficient. If the budget can support it, tailored software is also available, and can help better identify problems and savings.

In its simplest form, an energy monitoring system should be based on the following:

- Monthly utility billing and energy use data for the past 12 to 24 months
- Monthly production figures

Using a simple spreadsheet both can be plotted in various graphs to understand the relationship between energy use and production, and to identify any trends:

- Graph of energy use and production in a single graph over time
- Graph of energy costs and production in a single graph over time
- Graph of energy use on vertical axis against production on horizontal axis
- Graph of energy use divided by production (showing specific energy consumption)

Tools offered within commonly used spreadsheet packages can help to identify relationships and quantify trends. Graphs can be made for fuel and electricity separately, as well as for total energy use (showing both in the same units, such as megajoules or British thermal units) and costs.
Often the analysis will show periods of good performance and subpar performance—information that can help you set targets for energy consumption based on expected production volumes. Tracking energy use by entering new data and evaluating it as regularly as the data allows will help you to identify problems and improve energy savings.

Energy monitoring can also provide useful data for corporate GHG accounting initiatives. Successful monitoring programs regularly report energy use (sometimes daily) to identify increasing energy use and costs that could be caused by operational inefficiencies. Energy monitoring and metering systems can also help companies participate in emergency demand response programs, in which utility companies provide financial incentives to customers who reduce their energy loads during peak demand times.

4 Energy Efficiency Improvement Opportunities

There is a wide range of energy and cost saving measures that could be implemented in the U.S. baking industry. In order to improve energy efficiency and reduce the operational costs of a baking facility, several operations should be assessed. Firstly, baking plants use a number of cross-cutting equipment such as motors, air-compressors and boilers which consume a significant amount of energy and thus, need to be efficiently operated and properly maintained. Secondly, another area that requires attention is the efficient manufacture of baking products. The optimization of production processes and practices in baking along with the use of efficient equipment can result in significant cost savings.

Table 6 lists the cost saving opportunities considered in this Energy Guide. Opportunities are grouped into three categories: (1) opportunities that require no or negligible capital investment; (2) retrofit or upgrade opportunities that offer short payback periods (typically less than 3 years); and (3) opportunities that require new equipment or building modifications, and are therefore considered capital projects. The investment costs will vary from plant to plant, as they depend on a number of factors such as plant capacity and configuration, product type, plant location and operation characteristics. These opportunities are discussed in Sections 5 and 6.

Case study: Investing in energy efficiency

The Donetsk Bakery and Confectionery Factory—a major Ukrainian producer of bagels, crusts, and cakes—made a wide range of investments in energy efficiency in order to reduce operating costs and increase competitiveness. Through such measures as new ovens with steam generators, replacement of boilers, modernization of ventilation, building and piping insulation, and heat recovery the factory was able to save $800,000 per year. With an investment cost of $1.7 million, the overall simple payback period was less than 3 years (Ukranie Energy Efficiency Programme (UKEEP)

Table 6. Efficiency improvements considered in this Energy Guide

No capital investment	
Energy management	**Refrigeration systems**
Energy management programs	Good housekeeping
Energy assessments	Ensuring proper refrigerant charge
Lighting	Check for refrigerant contamination
Turn off lights in unoccupied areas	Efficient piping design
Establish lighting level standards	Minimize heat sources in cold storage areas
Heating, ventilation, and air conditioning	Raise system suction pressure
Commission and recommission	Keep condenser clean
Adjust non-production hours set-back temperatures	Reduce condenser fan use
Motor systems	Reduce condensing pressure
Develop a motor management plan	Cycle evaporator fans
Select motors strategically	Water defrosting
Maintain motors	**Baking processes**
Ensure motors are properly sized	Turn off ingredient conveyors when not in use
Minimize voltage unbalances	Proofer system maintenance
Compressed air systems	Strategic oven selection
Maintain compressed air systems	Proper oven placement
Reduce leaks	Minimize oven heat up time
Turn off unnecessary compressed air	Temperature profiling
Use lowest possible pressure	Oven and dryer maintenance
Properly size regulators	Reduce cleaning water use
Properly size pipes	Avoid compressed air for cleaning
Pump systems	Optimize product movement
Pump system maintenance program	**Water efficiency**
Monitor pump systems	Water management programs
Properly size pumps	Water use audits
Avoid throttling valves	Good housekeeping
Properly size pipes	Low pressure foam cleaning
Boilers	Pre-soaking of floors and equipment
Visual inspection	
Properly size boilers	
Steam distribution	
Maintain insulation	
Maintain steam traps	
Repair leaks	
Short payback period	
Lighting	**Steam distribution**
Use lighting controls	Improve insulation
Replace incandescent lamps with compact fluorescent lamps	Monitor steam traps
Replace T-12 tubes with T-8 or T-5 tubes	Recover flash steam
Replace mercury lamps	**Refrigeration systems**
Reduce HID voltage	Performance monitoring
Replace HID lighting with high-intensity fluorescent lights	Controls
Electronic ballasts	Piping insulation
LED lighting	Reduce heat infiltration
Heating, ventilation, and air conditioning	Reduce building heating loads
Energy monitoring and control systems	Optimized air flow pattern
Repair leaking ducts	Compressor control and scheduling
Variable air volume and adjustable speed drives	Floating head pressure control
Modify fans	Indirect lubricant cooling
Use ventilation fans	Adjustable speed drives
Efficient exhaust fans	Compressor heat recovery
Add building insulation	Automatic purging of condensers
Reflective roof coatings	Axial condenser fans
Motor systems	**Self generation**
Motor automation	Backpressure turbines
Adjustable speed drives	
Power factor correction	

Short payback period (continued)	
Compressed air systems	**Baking processes**
Monitor compressed air use	Reduce ingredient contamination/exposure
Modify the system instead of increasing pressure	Ingredient handling controls
Load management	Ingredient temperature controls
Controls	Adjustable speed drives on mixers
Reduce inlet air temperature	Heat recovery for proofer heating
Recover heat for water preheating	Flexible production (closed mesh belts)
Pump systems	Waste heat recovery on ovens and dryers
Reduce pump demand	Efficient oven burners
Controls	Oven combustion controls
High efficiency pumps	Oven process controls
Multiple pumps for variable loads	Cooling line controls
Trimming impellers	Efficient clean-in-place systems
Adjustable speed drives	Automated conveyors
Boilers	Automated pan stacking
Control boiler process	Refuse compacting
Reduce excess air	**Water efficiency**
Improve boiler insulation	Water efficient building fixtures
Condensate return	Small diameter hoses
Recover waste heat	Start/stop controls
Recover blowdown steam	Reduce cooling tower bleed-off
	High pressure, low volume sprays
Capital projects	
Lighting	**Self generation**
Daylighting (retrofit)	Combined heat and power
Heating, ventilation, and air conditioning	Tri-generation
Heat recovery systems	Photovoltaic panels
Solar air heating	Solar thermal concentration
Roof gardens	**Baking processes**
Compressed air systems	Continuous mixers
Install alternative equipment to eliminate compressed air	Radio frequency ovens/dryers
Boilers	Flexible production (multi-level ovens)
Upgrade old boilers	Upgrade freezers
Refrigeration systems	Parallel slicing
Free cooling (retrofit)	Twin-headed slicers
Cooling towers	Robotic movement
Dedicate a compressor to defrosting	Infrared ovens

5 Energy Efficiency Opportunities for Common Plant Systems

Energy efficiency is one of the lowest risk investments a company can make in its plants. Energy efficiency projects nearly always deliver sure savings. Further, energy savings contribute directly to the company's bottom line by reducing operating costs. As energy costs are forecast to increase over time, energy efficiency is a surefire method of reducing risk to a company.

Use Section 5 of this report to identify opportunities to control energy use in common plant systems. Common plant systems are those that are found in most manufacturing plants in the U.S. regardless of the industry. Many of the energy efficiency measures discussed in this section require either a limited investment or none at all.

Energy efficiency measures are described below by different end-use categories. Generally, each section begins with the easier-to-implement measures. For many measures typical savings are identified as are payback periods. Case studies of companies that implemented successful measures are included to highlight potential savings.

5.1.1 Building Lighting

Lighting contributes significantly to electrical energy consumption, and savings can be substantial. Lighting provides overall ambient light throughout manufacturing, storage, and office spaces and provides low-bay and task illumination in specific areas. Lighting demand is measured by a quantity of lumen of visible light needed at a certain point of time. The quantity of electricity (in watts) needed to supply the demand for lighting (in lumen) is expressed as the *efficacy* of the light source (in lumen/watt). The maximum theoretical efficiency is 700 Lumen/Watt. The term *luminaire* refers to the hardware, and *lamp* refers to the bulb. Another important parameter is the *color rendering index (CRI)*. The CRI is a measure of a light source's ability to show colors "naturally" compared to a familiar reference source, e.g. daylight. More information about factors to consider when choosing appropriate lighting is offered through the Lighting Research Center at Rensselaer Polytechnic Institute (LRC 2012).

Generally, high-intensity discharge (HID) sources—including metal halide, high-pressure sodium, and mercury vapor lamps—are used for manufacturing and storage areas. Fluorescent, compact fluorescent (CFL), and incandescent lights are typically used for task lighting and offices. Lighting controls should be used in all areas of the plant.

Case study: Efficient lighting by design

The Bakers Delight showcase bakery outside of Sydney, Australia, was designed to demonstrate best practices in energy efficient bakery design. Among its many efficient technologies is a state-of-the-art efficient lighting system that includes both high-efficiency T5 fluorescent lamps and 35W metal halide lamps. The system provides the same lighting levels as standard bakeries, but with 64% less energy. Additionally, the system is split into two circuits, with one being small enough to provide safe access when the bakery is not operational (DITR 2003).

Only a small part of the energy used in a lighting fixture results in lighting; the remainder is lost as heat. So, even when lighting is a relatively small part of a plant's energy use, it may be possible to find considerable energy savings from using more efficient lighting systems. For specific applications, such as lighting in refrigerated or air conditioned spaces, increasing lighting efficiency (and therefore reducing heat) may result in other savings. Next to energy use, the lifetime of a lamp is important because a long lamp life also reduces maintenance costs.

Table 7 provides an overview of the typical performance and applications of various lamp types.

Table 7. Performance comparison of lighting sources

Lamp	Efficacy (Lumen/watt)	Typical Lifetime (Hours)	Applications
Incandescent	5–20	1,000	Task
Halogen	<24	1,000	Task
CFL	20–70	8,000–15,000	Task
Fluorescent T-12	60	20,000	Any
Fluorescent T-8	80–100	20,000	Any
Fluorescent T-5	80–105	20,000	Any
Mercury Vapor	30-50	60,000	Hi-Bay
Induction	80	100,000	Exterior, Hi-Bay
High Pressure Sodium	85–150	10,000–50,000	Exterior, Hi-Bay
Metal Halide	70–115	20,000	Hi-Bay
LED	10–120	50,000	Task

Note: Values are typical performance. Performance of individual products may vary. The performance of fluorescent lamps assumes the use of an electronic ballast. Technology development may change the future performance of specific lighting technologies.

The ENERGY STAR program suggests cost-effective ways to save on lighting energy. Measures to improve lighting efficiency include simple measures such as switching off the lights to replacing lights and fixtures to installing innovative lighting systems. Check with your local electric utility to see what programs and incentives they may offer to help improve lighting performance.

Turn off lights in unoccupied areas. Encourage personnel to turn off lights in unoccupied building spaces. An awareness program will help staff get in the habit of switching off lights and other equipment when not in use. Often, lights are on in areas (such as warehouses or parts of production areas) at times when they are not needed, and occupancy controls may help to reduce energy waste (see “Use lighting controls” below).

Case study: Induction lights

The Fabulous Bakin’ Boys are a UK-based producer of muffins, pancakes, and cakes. The company was able to reduce its plant lighting load from 26.4kW to 8.3 kW through the use of induction low bay fixtures, which reduced lighting energy costs by 68%. The induction lamps have an expected life of 10 years of continuous operation, and the payback period for the investment was under 18 months (Green Business Light (GBL) 2012).

Establish lighting level standards. For both new facilities and retrofits, lighting levels (expressed as lumen per surface area) should be set in the design of each section of a plant and followed in ordering, manufacturing, and installation. Work with both manufacturers and suppliers to ensure that the proper system is installed.

Lighting standards can be set for different work areas. For example, Toyota set different lighting standards for quality check areas, warehouses, and office buildings. By setting a lumen/surface area standard and sticking to it, Toyota claims savings of 30% on lighting energy use. Moreover, lighting levels were reduced in areas that need lighting only for safety (such as automated warehouses and robot-operated process areas). Similarly, use of sections in a plant may change over time (for example, from assembly to storage), resulting in overlit areas. Conduct plant energy assessments with this point in mind. Ford Motor Company reduced energy costs for lighting by eliminating some lights in overlit areas.

Use lighting controls

Automatic controls. Lights should be shut off during non-working hours through automatic controls. Occupancy sensors turn off lights when a space is unoccupied. Occupancy sensors can save 10% to 20% of a facility's lighting energy use. Numerous case studies suggest an average payback period of one year. Daylight controls for indoor and outdoor lights can adjust lighting intensity based on the availability of daylight.

Manual controls. Manual controls can be used in conjunction with automatic controls to save additional energy in smaller areas. One of the easiest measures is to install switches to allow occupants to control lights. If automatic controls are not possible, some companies have found success in developing and enforcing a "lights out" program where specific employees are tasked with turning lights off at appropriate times.

Case study: Occupancy sensors

An energy audit revealed that a U.S. bread plant could reduce its electricity use by 25 MWh/year through the installation of low-cost occupancy sensors throughout its facility. At a cost of only $2,900, the occupancy sensors would save $3,400 per year and pay for themselves in only 10 months (BASE 2012).

Lighting controls in practice. An example of an energy-efficient lighting control is illustrated in Figure 3, which depicts five rows of overhead lights in a workspace. During the brightest part of the day, ample daylight for most of the room is provided by the window, so only row C would need to be lit. At times when daylight levels drop, all B rows would be lit and row C would be turned off. Only at night or on very dark days would it be necessary to have both rows A and B lit. These methods can also be used as a control strategy on a retrofit by adapting the luminaires already present.

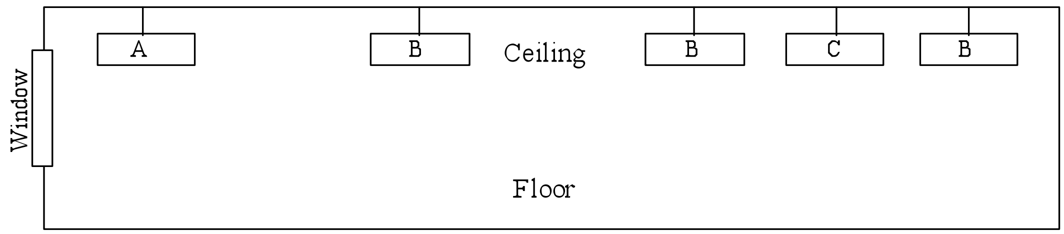

Figure 3. Lighting placement and controls

Use daylighting. *Daylighting* involves the efficient use of natural light in buildings to minimize the need for artificial lighting. Increasing levels of daylight within rooms can reduce electrical lighting loads by up to 70% (CADDET 2001) (IEA 2000). Unlike conventional skylights, an efficient daylighting system may provide evenly dispersed light without creating heat gains, reducing the need for cooling compared to skylights. Daylighting is applied primarily to new buildings and incorporated at the design stage. However, existing buildings can sometimes be cost-effectively refitted with these systems.

Daylighting technologies include properly placed and shaded windows, atria, clerestories, light shelves, and light ducts—all of which can accommodate various angles of the sun and redirect daylight using walls or reflectors. Because daylighting is variable, it is almost always combined with artificial lighting to ensure the necessary illumination on cloudy days or after dark. Combining daylighting with lighting controls can maximize its benefits. More information can be found at the website of the Daylighting Collaborative led by the Energy Center of Wisconsin (ECOW 2012).

Replace incandescent lamps with compact fluorescent lamps (CFL). A fluorescent lamp lasts roughly ten times longer than an incandescent light and is significantly more energy efficient. The payback period for the replacement varies, but it can be as low as five months.

Replace T-12 tubes with T-8 or T-5 tubes. T-12 lighting tubes are the long fluorescents 12/8 inches in diameter (the "T" designation refers to a tube's diameter in terms of 1/8 inch increments). Many industrial facilities still use these tubes. T-12 tubes consume significant amounts of electricity, and also have poor efficacy, lamp life, lumen depreciation, and color rendering index. As a result, T-12 maintenance and energy costs are high. T-8 and T-5 lighting tubes have about twice the efficacy of T-12 tubes and can last up to 60% longer, which leads to reduced maintenance cost savings. For example, typical energy savings from the replacement of a T-12 lamp by a T-8 lamp are about 30% (Galitsky et al. 2005).

Case study: T-8 lamps

The J&J Snack Foods 100,000-square-foot Bellmawr, New Jersey, plant was equipped with antiquated lighting that required increasing maintenance. The plant switched to energy-efficient, long-life T-8 lamps with electronic ballasts, which led to annual energy savings of $18,000 with a simple payback period of only 12 months (South Jersey Energy

Replace mercury lamps. Where color rendition is critical, metal halide lamps can replace mercury or fluorescent lamps with energy savings of up to 50%. Where color rendition is not critical, high-pressure sodium lamps offer energy savings of 50% to 60% compared to mercury lamps.

Reduce high-intensity discharge (HID) voltage. Reducing lighting system voltage can also save energy. Commercially available voltage controllers can easily be fitted to a central panel switch and constrict the flow of electricity to lighting fixtures, thereby reducing voltage and saving energy, with an imperceptible loss of light. A Toyota production facility installed reduced-voltage HID lights and reduced lighting energy consumption by 30%. Voltage controllers work with both HID and fluorescent lighting systems and are available from multiple vendors.

Consider replacing HID lighting with high-intensity fluorescent lights. Traditional HID lighting can be replaced with T-5 high-intensity fluorescent lighting systems, which incorporate high-efficiency fluorescent lamps, electronic ballasts, and high-efficacy fixtures that maximize output to work areas. These systems can often have lower energy consumption, lower lumen depreciation over the lifetime of the lamp, better dimming options, faster startup and re-strike capabilities, better color rendition, higher pupil lumen ratings, and improved glare performance than traditional HID systems. The payback period is typically below three years, but it can be as low as a few months, since many electrical utility companies offer rebates to replace inefficient lighting.

Replace magnetic ballasts with electronic ballasts. A ballast regulates the amount of electricity required to start a lighting fixture and maintain steady light output. Electronic ballasts can require 12% to 30% less power than their magnetic predecessors. New electronic ballasts have smooth and silent dimming capabilities, in addition to longer lives (up to 50% longer), faster run-up times, and cooler operation than magnetic ballasts. New electronic ballasts also have automatic switch-off capabilities for faulty or end-of-life lamps (Cook 1998, Galitsky et al. 2005, Eley et al. 1993)

LED lighting. Light Emitting Diode (LED) lights have been receiving a lot of attention as the next generation of energy efficient lighting. In typical florescent lighting, electrical arcs are used to excite mercury and phosphorous compounds, which then emit light. On the other hand, LED lights are semiconductor diodes that use far less energy to emit the same lumens of light. Several new LED light products are emerging on the market and are compatible with current light fixtures, such as T-8 light fixtures (Myer and Paget 2009).

5.1.2 Building HVAC

HVAC stands for heating, ventilation, and air conditioning and refers to the equipment, distribution network, and terminals used either collectively or individually to provide fresh filtered air, heating, cooling, and humidity control in a building. The main goals of HVAC are to provide comfort and indoor air quality, which depend on many factors, such as thermal regulation, control of internal and external sources of pollutants, supply of acceptable air, removal of unacceptable air, occupant's activities and preferences, and proper operation and maintenance of building systems (ASHRAE 2005).

Air exchange between outdoor and indoor air is needed to maintain good air quality and agreeable indoor temperatures. Two processes—ventilation and infiltration—affect this exchange. *Ventilation* is intentional use of air to provide acceptable indoor air, either through natural movement (such as windows and doors) or mechanical means, by using fans or vents. *Infiltration* is the flow of outdoor air into a building through cracks and other unintentional openings, and should be minimized.

Air and water are heated by means of a boiler, furnace, or heat pump, and they are distributed evenly through ducts for air or pipes and radiators for water. Air cooling is performed by cooling coils (based on refrigeration cycles) or evaporation (when the incoming air humidity is low). Many combinations of heating and cooling sources supply the HVAC system. With heating, for example, a gas- or oil-fired boiler or furnace, heat pump, rooftop unit, new technology (such as infrared radiation), or electric heat could be employed. For cooling, common sources include rooftop units, chillers, heat pumps, air conditioners, or off-peak cooling systems.

Employ an energy-efficient system design. For HVAC systems in new industrial facilities, the greatest opportunities for energy efficiency arise at the design stage. Sizing equipment properly and designing energy efficiency into a new facility generally minimizes the energy consumption and operational costs of HVAC systems from the outset. This practice often saves money in the long run, as it is generally cheaper to install energy-efficient HVAC equipment during construction than it is to upgrade an existing building with an energy-efficient system later on, especially if those upgrades lead to downtime.

Commission and recommission. Before replacing HVAC system components to improve energy efficiency, explore the possibility of HVAC system recommissioning. Recommissioning is essentially the same process as commissioning, but it is applied to a building's existing HVAC, controls, and electrical systems (U.S. EPA2008).

Commissioning is the process of verifying that a new building functions as intended and communicating the intended performance to the building management team. This usually occurs when a new building is turned over for occupancy. In practice, commissioning costs are not included in design fees and often compete with other activities, so commissioning is seldom pursued properly. To

Case study: Energy efficiency by design

Recently, Mission Foods (one of the world's largest tortilla and corn chip manufacturers) worked with Southern California Edison (its local utility company) to design its new production facility in Rancho Cucamonga to be as energy efficient as possible. The new facility had 50,000 square feet of office space, 125,000 square feet of manufacturing space, and 134,000 square feet of warehouse space. Mission Foods chose to install energy-efficient technologies for its HVAC systems and lighting systems, room occupancy sensors that turned off lights automatically, low-emissivity windows that reduced building heat gain, and skylights that provided natural lighting. The total project (which also included refrigeration system measures) allowed the company to reduce the electricity consumption of its new facility by roughly 18% compared to its existing facilities, leading to annual energy savings of over $300,000 per year (Energy Design Resources (EDR) 2005) ensure that energy performance and operational goals are met, however, the building must be commissioned. To achieve this, ENERGY STAR recommends the following:

- Communicate your energy performance goals during commissioning to ensure that the design target is met. Encourage energy-use tracking so that performance comparisons are made over time.
- Specify detailed commissioning activities in project contracts. Seek separate funding for commissioning work, to ensure that it will get done and be done well.
- Hire building commissioning experts. Include the commissioning firm as part of the design team early in the project.
- Finalize and transfer a set of technical documents, including manufacturers' literature for systems and components. Supplement technical literature with summaries of how to operate and manage the systems. Provide additional explanation for innovative design features.

Recommissioning involves a detailed assessment of existing equipment performance and maintenance procedures. This is compared to the intended or design performance and maintenance procedures in order to identify and fix problem areas that might be hampering building energy efficiency. Recommissioning can be a cost-effective retrofit in itself, sometimes generating more savings than the cost of the retrofit measure. For example, recommissioning may help avoid the need to install new or additional equipment, leading to savings in capital investments.

The U.S. EPA's ENERGY STAR Building Upgrade Manual (U.S. EPA2008) recommends a stepwise approach to recommissioning, in which a series of strategically-ordered building "tune up" strategies are pursued. First, lighting and supplemental loads should be assessed, then the building envelope, then controls, then testing, adjusting and balancing, then heat exchange equipment, and finally heating and cooling systems. Most of these steps relate to HVAC system components or factors that will directly affect HVAC system energy consumption (such as building envelope and lighting). For more information, consult the manual.

Install energy monitoring and control systems. An energy monitoring and control system supports the efficient operation of HVAC systems by monitoring, controlling, and tracking system energy consumption. Such systems continuously manage and optimize HVAC system energy consumption while also providing building engineers and energy managers with a valuable diagnostic tool for tracking energy consumption and identifying potential HVAC problems. Several projects indicate that the average payback period for HVAC control systems is about 1.3 years (IAC 2011).

Adjust non-production hours set-back temperatures. Setting back building temperatures (that is, adjusting building temperatures down in the winter or up in the summer) during periods of non-use, such as weekends or non-production times, can significantly reduce HVAC energy consumption.

Repair leaking ducts. Leaking air ducts can waste significant amounts of energy. Install duct insulation and perform regular duct inspection and maintenance, including ongoing leak detection and repair. According to a study by Lawrence Berkeley National Laboratory, repairing duct leaks in industrial and commercial spaces can reduce HVAC energy consumption by up to 30%. The study also showed that duct tape should not be used for leak repair; aerosol sealants are preferred (Masanet et al. 2008).

Consider variable-air-volume systems. Variable-air-volume systems adjust the rate of air flow into a room or space based on the current air flow requirements of that room or space. Variable-air-volume systems therefore work to more closely match HVAC load to heating and cooling demands, which reduces energy use.

Install adjustable-speed drives (ASDs). Adjustable speed drives can be installed on variable-volume air handlers and recirculation fans to match precisely the flow and pressure requirements of air handling systems. Energy consumed by fans can be lowered considerably since they do not constantly run at full speed. Adjustable-speed drives can also be used on chiller pumps and water systems pumps to minimize power consumption based on system demand.

Consider heat recovery systems. Heat recovery systems reduce the energy required to heat or cool facility intake air by recovering the thermal energy of the exhaust air. Common heat recovery systems include heat recovery wheels, heat pipes, and run-around loops. The efficiency of heat pipes is in the 45% to 65% range (U.S. EPA 2003), while the efficiency of run-around loops can be slightly higher, in the 55% to 65% range (U.S. EPA2001).

Modify your fans. Changing the size or shape of the sheaves of a fan can help to optimize fan efficiency and airflow, reducing energy consumption. Toyota optimized the sheaves of its fans instead of installing adjustable-speed drives (ASDs) on fans, finding better savings and payback periods than expected (Galitsky et al. 2005).

Use ventilation fans. Ventilation fans installed in the ceilings of work areas can help destratify workspace air, leading to better circulation of cool air in summer and warm air in winter, as well as more even temperature distributions from floor to ceiling. Such fans can help reduce the load on building heating systems by helping to "push down" warm air that rises during heating months.

Install efficient exhaust fans. Exhaust fans are standard components in any HVAC system. Mixed flow impeller exhaust fans offer an efficient alternative to traditional centrifugal exhaust fans. They are typically 25% more efficient than

Case study: Ventilation fans

Yasama Corporation U.S.A., a manufacturer of soy sauce, installed new high bay ceiling fans to improve air circulation at its Salem, Oregon, facility in 2004. Previously the company operated ceiling-mounted heaters with 15 hp fans in its production area. However, the fans didn't de-stratify the air in the production area's tall ceilings, nor take advantage of the heat given off by process equipment. Furthermore, to provide ventilation in the summer, the company ran the heater fans in "fan only" mode in conjunction with six 3 hp exhaust fans to remove hot air. The new high-bay ceiling fans were operated using only 1.5 hp motors, which were expected to lead to electrical energy savings of 48,000 kWh per year and electricity cost savings of $2,500 (Food Processing Industry Resource Efficiency (FIRE) Project 2005a). Furthermore, the company expected to save significant amounts of natural gas in heating centrifugal fans and can be cheaper to install and maintain. The expected payback period is about two years (Tetley 2001).

Add building insulation. Adding insulation will reduce utility bills. Older buildings are likely to use more energy than newer ones, leading to very high heating and air conditioning bills. However, even in new buildings, adding insulation may reduce utility bills enough to pay for itself within a few years.

Various states have regulations and guidelines for building insulation—for example, California's Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24) (CEC 2012). Going beyond regulated insulation levels may be economically beneficial and should be considered as part of a new building's design, as well as for reconstruction of existing buildings. For refrigerated warehouses, much higher levels of insulation are preferred.

Employ solar air heating. Solar air heating systems, such as Solarwall®, use conventional steel siding painted black to absorb solar radiation for insulation. Fresh air enters the bottom of the panels where it is heated as it passes over the warm absorber, and fans distribute the air. This measure is best applied at buildings in cold climates, and the potential benefits should be analyzed based on each site's local conditions.

Case study: Solar air heating

Using a solar air heating system, the Ford Motor Company's Chicago Stamping Plant turned its south wall into a huge solar collector (CREST 2001). Energy savings were estimated to be over $300,000 per year compared to conventional natural gas air systems. Capital costs were $863,000 (about $15 per square foot, including installation), resulting in a payback period of less than three years. In addition to energy savings, the system was said to provide clean fresh air for employees.

Improve building reflection. Use of a reflective coating on the roof of buildings in sunny, hot climates can save on air conditioning costs inside. Two medical offices in Northern California used reflective roofs on their buildings; one reduced air conditioning demand by 8%, the other reduced air conditioning demand by 12% (Konopacki et al. 1998). For colder climates, heat lost due to cool roofs (in winter, for example) also needs to be taken into account, and often negates savings. In addition to location and weather, other primary factors influence energy savings, such as roof insulation, air conditioning efficiency, and building age. Reflective roof materials are available in different forms and colors.

Roof gardens on a flat roof improve the insulation of buildings against both hot and cold by providing both heat (in winter) and air conditioning (in summer). In winter, green roofs can freeze, so they carry a slight heating penalty but often still yield net energy savings (Holtcamp 2001). In addition, a roof garden can increase the lifetime of the roof, provide and reduce runoff, and reduce air pollution and dust. Today, Germany installs over 10 million ft^2 of green

Case study: Green roofs

The Gap Headquarters in San Bruno (California) installed green roofs in 1997 (Greenroofs.com 2001). In addition to saving energy and lasting longer than traditional roofs, a roof garden absorbs rain, slowing run-off to local storm drains.

roofs a year, helped in part by economic incentives (Holtcamp 2001).

Other simple options for decreasing building HVAC energy use exist for certain conditions. Shade trees reduce cooling for hot climates. Shade trees should be deciduous trees (providing shade in the summer and none in the winter) and planted on the west and southwest sides of the building (based on the path of the summer sun) (McPherson and Simpron 1995). Trees planted on the north side of the building in cold climates can reduce heating in winter by shielding the building from the wind. Vines can provide both shade and wind shielding.

5.1.3 Motors

Motors are a major industrial electricity consumer and are used in many plant systems, such as HVAC, compressed air, refrigeration and cooling, and various processes. This section applies to any system that uses motors. Examples are used to detail specific applications and their success.

When considering energy efficiency improvements to a facility's motor systems, take a "systems approach." Rather than considering the energy efficiency of just the motor, the systems approach strives to optimize the energy efficiency of the entire motor system (including the motor; driven equipment such as pumps, fans, and compressors; and controls). A systems approach analyzes both the energy supply and energy demand sides of motor systems, as well as how both sides interact to optimize total system performance. The focus is on both energy use and system uptime and productivity. The U.S. DOE provides a variety of resources for improving industrial motor system efficiency, which can be consulted for more detailed information on many of the measures presented in this section. The U.S. DOE's Improving Motor and Drive System Performance, A Sourcebook for Industry is a particularly helpful resource (U.S. DOE 2008a). Also, many tips, tools, and industrial case studies on motor system efficiency can be found at the U.S. DOE's BestPractices website (U.S. DOE 2012d). The Motor Decisions Matter^{SM} Campaign also provides a number of excellent resources for improving motor system efficiency (MDM 2007).

A systems approach for motors typically involves the following five steps (SCE 2003):

1. Locate and identify all motors in the facility.
2. Document conditions and specifications of each motor to provide a current systems inventory.
3. Assess the needs and the actual use of the motor systems to determine whether or not motors are properly sized and how well each motor meets the needs of its driven equipment.
4. Collect information on potential repairs and upgrades to the motor systems, including the economic costs and benefits of implementing repairs and upgrades, to enable the energy efficiency improvement decision-making process.
5. If upgrades are pursued, monitor the performance of the upgraded motor systems to determine actual costs savings.

The motor system energy efficiency measures below reflect important aspects of this approach, including matching motor speeds and loads, proper motor sizing, and upgrading system components.

Develop a motor management plan. A motor management plan is an essential part of a plant's energy management strategy. It helps support long-term motor system energy savings and ensures that motor failures are handled quickly and cost effectively. The National Electrical Manufacturers Association (NEMA) and other organizations have created the Motor Decisions Matter℠ campaign to help industrial and commercial customers evaluate their motor repair and replacement options, promote cost-effective applications of NEMA Premium® motors and "best practice" repair, and support the development of motor management plans before motors fail. The national campaign suggests the following actions for a sound motor management plan (MDM 2007):

1. Create a motor survey and tracking program.
2. Develop guidelines for proactive repair/replace decisions.
3. Prepare for motor failure by creating a spares inventory.
4. Develop a purchasing specification.
5. Develop a repair specification.
6. Develop and implement a predictive and preventive maintenance program.

The Motor Decisions Matter Campaign's Motor Planning Kit (MDM 2007).

Select motors strategically. Important factors to consider when selecting a motor include speed, horsepower, enclosure type, temperature rating, efficiency level, and quality of power supply. When selecting and purchasing a motor, consider the motor's life-cycle costs rather than just its initial purchase and installation costs. Up to 95% of a motor's costs can be attributed to the energy it consumes over its lifetime, while only about 5% of a motor's lifetime costs are attributed to its purchase, installation, and maintenance (MDM 2007). Life cycle costing (LCC) is an accounting framework that enables users to calculate total ownership costs of different investment options, leading to a sound evaluation of competing motor purchasing, repair, or replacement alternatives. A specific LCC guide developed for pump systems (Hydraulic Institute, Europump, and U.S. DOE 2001) provides a general introduction to LCC for motor systems.

Motor efficiency. Selecting energy-efficient motors is an important strategy for reducing motor system life-cycle costs because they reduce energy losses through improved design, better materials, tighter tolerances, and improved manufacturing techniques. With proper installation, energy-efficient motors can also run cooler (which may help reduce facility heating loads) and have higher service factors, longer bearing life, longer insulation life, and less vibration.

To be considered energy-efficient in the United States, a motor must meet NEMA performance criteria. The Consortium for Energy Efficiency (CEE) has described the evolution of standards for energy-efficient motors in the United States, which is helpful for understanding the "efficient" motor nomenclature (CEE 2007):

- NEMA energy-efficient motor standard (NEMA EE) was developed in the mid-1980s (NEMA2002), and in 1992 the Energy Policy Act (EPACT) required that many motors comply with NEMA "energy-efficient" ratings if sold in the United States.
- A CEE Premium Efficiency Criteria specification was designed in 1996 to promote motors with higher efficiency levels than EPACT required.
- In 2001, the NEMA Premium Efficiency Electric Motor specification was developed to address confusion with respect to what constituted the most efficient motors available in the market. This specification was developed by NEMA, CEE, and other stakeholders,

and was adapted from the CEE 1996 criteria. It currently serves as the benchmark for premium energy-efficient motors. NEMA Premium® also denotes a brand name for motors which meet this specification. Specifically, this specification covers motors with the following attributes:

- Speed: 2-, 4-, and 6-pole
- Size: 1 to 500 horsepower (hp)
- Design: NEMA A and B
- Enclosure type: open and closed
- Voltage: low and medium voltage
- Class: general, definite, and special-purpose

The choice of whether or not to install a premium efficiency motor strongly depends on (1) motor operating conditions, and (2) the life cycle costs associated with the investment. In general, premium efficiency motors are most economically attractive when replacing motors with an annual operation exceeding 2,000 hours/year. Software tools such as MotorMaster+ (see Tools for Self-Assessment in Appendix C) can help identify attractive applications of premium efficiency motors based on specific plant conditions. Given the quick payback time, it usually makes sense to buy the most efficient motor available.

Sometimes, even replacing an operating motor with a premium efficiency model may have a low payback period. According to data from the Copper Development Association, the upgrade to high-efficiency motors, as compared to motors that achieve the minimum efficiency as specified by EPACT, can have paybacks of less than 15 months for 50 hp motors (CDA 2001). Payback times will vary based on size, load factor, running time, local energy costs, and available rebates and/or incentives (see Appendix D). Given the quick payback time, it usually makes sense to by the most efficient motor available (U.S. DOE 2003).

Case study: High efficiency motors

An energy audit revealed that a U.S. bread plant could reduce its electricity use by 35 MWh/year through the installation of high efficiency motors. At a cost of only $2,300, the occupancy sensors would save $4,500 per year and pay for themselves in only 6 months (BASE 2012).

Rewind versus replace. In some cases, it may be cost-effective to rewind an existing energy-efficient motor instead of purchasing a new one. As a rule of thumb, when rewinding costs exceed 60% of the costs of a new motor, purchasing the new motor is a better choice (MDM 2007). If you do decide to rewind, choose a motor service center that follows best-practice motor rewinding standards in order to minimize potential efficiency losses. An ANSI-approved recommended best-practice standard has been offered by the Electric Apparatus Service Association (EASA) for the repair and rewinding of motors (EASA 2006). When best rewinding practices are implemented, efficiency losses are typically less than 0.5% to 1% (EASA 2003). However, poor quality rewinds may result in larger efficiency losses, so it is important to ask whether the motor service center follows EASA best practice standards (EASA 2006).

Maintain your motors. The purposes of motor maintenance are to prolong motor life and to foresee a motor failure. Motor maintenance measures can be categorized as either preventative or predictive. Preventative measures, the purpose of which is to prevent unexpected downtime of motors, include electrical consideration, voltage imbalance minimization, load consideration, and motor ventilation, alignment, and lubrication. The purpose of predictive motor maintenance is to observe ongoing motor temperature, vibration, and other operating data to identify when it becomes necessary to overhaul or replace a motor before failure occurs (Barnish, Muller, and Kasten 1997). The savings associated with an ongoing motor maintenance program are significant, and could range from 2% to 30% of total motor system energy use (Efficiency Partnership 2004). An IAC case study of a U.S. dairy plant found that implementing a motor maintenance plan resulted in a simple payback period of about 4 months (IAC 2011).

Ensure that motors are properly sized. Inappropriately sized motors result in unnecessary energy losses - if peak loads on driven equipment can be reduced, so can motor size. Replacing oversized motors with properly sized motors saves U.S. industry, on average, 1.2% of total motor system electricity consumption (Xenergy 1998). Higher savings can often be realized for smaller motors and individual motor systems.

To determine the proper motor size, gather the following data: load on the motor, operating efficiency of the motor at that load point, the full-load speed of the motor to be replaced, and the full-load speed of the replacement motor. The U.S. DOE's BestPractices program provides fact sheets that can help you to decide whether to replace oversized and under-loaded motors (U.S. DOE 2012c). Additionally, software packages such as MotorMaster+ (see Tools for Self-Assessment Appendix C) help in proper motor selection.

Motor Automation. Motors should only run when needed. A 10% reduction in motor operating time may save more energy than replacing a conventional motor with a NEMA Premium® efficiency motor (U.S. DOE 2008b). Automatic shutdown of motors that would otherwise be left idling can reduce energy costs without requiring high investment.

Although there is a concern that increasing motor start-ups will negatively affect the motor's lifetime, the lifetime will not be significantly affected as long as the frequency of motor start-ups is not excessive (U.S. DOE 2008b). NEMA (2001) gives the maximum number of allowable motor start-ups per hour and the duration of rest time between start-ups, for various horsepower motors and synchronous speed ratings.

Consider adjustable speed drives (ASDs).

Adjustable-speed drives better match speed to load requirements for motor operations, and therefore ensure that motor energy use is optimized to a given application. These systems are offered by many suppliers worldwide. Energy savings may vary from 7% to as high as 60%, depending on the use pattern of the motor (Worrell, Bode, and de Beer 1997). Computer controls can be used with ASDs to control the adjustment of power to match demand.

Correct power factor. Inductive loads like transformers, electric motors, and HID lighting may cause a low power factor, resulting in increased power consumption and electricity costs. The power factor can be corrected by minimizing idling of electric motors (a motor that is turned off consumes no energy), replacing motors with premium-efficient motors (see above), and installing capacitors in the AC circuit to reduce the magnitude of reactive power in the system.

Minimize voltage unbalances. A voltage unbalance degrades the performance and shortens the life of three-phase motors. A voltage unbalance causes a current unbalance, which will result in torque pulsations, increased vibration and mechanical stress, increased losses, and motor overheating, which can reduce the life of a motor's winding insulation. Voltage unbalances may be caused by faulty operation of power factor correction equipment, an unbalanced transformer bank, or an open circuit. A rule of thumb is that the voltage unbalance at the motor terminals should not exceed 1%. Even a 1% unbalance will reduce motor efficiency at part load operation, while a 2.5% unbalance will reduce motor efficiency at full load operation.

For a 100 hp motor operating 8,000 hours per year, a correction of the voltage unbalance from 2.5% to 1% will result in electricity savings of 9,500 kWh or almost $500 at an electricity rate of $0.05/kWh (U.S. DOE 2005).

By regularly monitoring the voltages at the motor terminal and through regular thermographic inspections of motors, voltage unbalances may be identified. It is also recommended to verify that single-phase loads are uniformly distributed and to install ground fault indicators as required. Another indicator that a voltage unbalance may be a problem is 120 Hz vibration, which should prompt an immediate check of voltage balance (U.S. DOE 2005). The typical payback period for voltage controller installation on lightly loaded motors in the United States is 2.6 years (IAC 2011).

5.1.4 Compressed Air

Compressed air is the most expensive form of energy used in an industrial plant because of its poor efficiency, which is typically about 10% from start to end use (U.S. DOE 2003). If compressed air is used, it should be at the minimum quantity for the shortest possible time, and it should be constantly monitored and reweighed against alternatives. Many energy-reduction opportunities in compressed air systems are not prohibitively expensive, and payback periods for some are extremely short, often less than one year. The U.S. DOE provides a variety of resources for improving industrial compressed air system efficiency, which can be consulted for more detailed information on many of the measures presented in this section. The U.S. DOE's Improving Compressed Air System Performance, A Sourcebook for Industry is a particularly helpful resource (U.S. DOE 2003). Also, many tips, tools, and industrial case studies on compressed air system efficiency can be found at the U.S. DOE's BestPractices website (U.S. DOE 2012d).

Here are some key compressor facts related to energy efficiency:

- Air receivers can be employed near high-demand areas to provide a supply buffer to meet short-term demand spikes that can exceed normal compressor capacity. In this way, required online compressors may be reduced.
- Multiple-stage compressors theoretically operate more efficiently than single-stage compressors. Replacing single stage compressors with two-stage compressors typically provides a payback period of 2 years or less.
- Many multi-stage compressors save energy by cooling the air between stages, reducing the volume and work required to compress the air.

- Using multiple smaller compressors instead of one large compressor can save energy as well.
- Large compressors consume more electricity when they are unloaded than do multiple smaller compressors with similar overall capacity.
- An analysis of case studies around the country shows an average payback period of about 1.2 years.

Maintain compressed air systems. Inadequate maintenance can lower compression efficiency and increase air leakage or pressure variability, and can lead to increased operating temperatures, poor moisture control, and excessive contamination of compressed air system components. Better maintenance will reduce these problems and save energy.

The following bullets summarize compressed air problems and maintenance solutions (Radgen and Blaustein 2001, Scales and McCulloch 2007, U.S. DOE 2003):

- *Blocked pipeline filters increase pressure drop*. Keep the compressor and intercooling surfaces clean and foul-free by inspecting and periodically cleaning filters. Seek filters with just a 1 pound per square inch (psi) pressure drop. The payback period for filter cleaning is usually under two years. Fixing improperly operating filters will also prevent contaminants from entering into tools, which causes them to wear out prematurely. Generally, when pressure drop exceeds 2 to 3 psig, replace the particulate and lubricant removal elements. Inspect all elements at least annually. Also, consider adding filters in parallel to decrease pressure drop. Expect a 2% reduction of annual energy consumption in compressed air systems when filters are changed frequently.
- *Poor motor cooling* can increase motor temperature and winding resistance, shortening motor life and increasing energy consumption. Keep motors and compressors properly lubricated and cleaned. Sample and analyze compressor lubricant every 1000 hours and ensure that it is at the proper level. In addition to energy savings, this maintenance can help avoid system corrosion and degradation.
- *Inspect fans and water pumps* regularly to ensure proper performance.
- *Inspect drain traps* periodically to ensure they are not stuck in either the open or closed position and are clean. Some users leave automatic condensate traps partially open at all times to allow for constant draining; however, this practice wastes substantial amounts of energy and should never be implemented. Instead, install simple pressure-driven valves. Clean and repair malfunctioning traps instead of leaving them open. Some automatic drains or valves do not waste air, such as those that open when condensate is present. According to vendors, inspecting and maintaining drains typically has a payback period of less than two years.
- *Maintain the coolers* on the compressor and the aftercooler to ensure that the dryer gets the lowest possible inlet temperature.
- If using compressors with belts, *check the belts* for wear and adjust them. A good rule of thumb is to adjust them every 400 hours of operation.
- *Check water cooling systems* for water quality (pH and total dissolved solids), flow, and temperature. Clean and replace filters and heat exchangers as suggested by the manufacturer.
- *Minimize leaks* (see also "Leaks" below).
- *Specify pressure regulators* that close when failing.

- Applications requiring compressed air should be *checked for excessive pressure*, duration, or volume. They should be regulated, either by production line sectioning or by pressure regulators on the equipment itself. Tools not required to operate at maximum system pressure should use a quality pressure regulator, since poor quality regulators tend to drift and lose more air. Otherwise, the unregulated tools operate at maximum system pressure at all times and waste excess energy. System pressures operating too high also result in shorter tool life and higher maintenance costs.

Monitor compressed air use. As with maintenance, proper monitoring of compressed air systems can save energy and money. Proper monitoring includes the following (CADDET 1997):

- Pressure gauges on each receiver or main branch line, and differential gauges across dryers and filters. Temperature gauges across the compressor and its cooling system to detect fouling and blockages.
- Flow meters to measure the quantity of air used.
- Dew point temperature gauges to monitor air dryer effectiveness.
- Kilowatt-hour meters and hours-run meters on the compressor drive.

Reduce leaks in pipes and equipment. Air leaks can be a significant source of wasted energy. A typical plant that has not been well maintained could have a leak rate between 20% to 50% of its total compressed air production capacity. Leak repair and maintenance can reduce this number to less than 10%. Overall, fixing leaks in a compressed air system is projected to reduce annual energy consumption by 20% (Radgen and Blaustein 2001).

The magnitude of a leak varies with the size of the hole in the pipes or equipment. It is estimated that losses based on a compressor operating 2,500 hours per year at 6 bar (87 psi) will experience the following losses (CADDET 1997):

- With a leak diameter of 0.02 inches (½ millimeter [mm]): 250 kWh/year
- With a leak diameter of 0.04 in. (1 mm): 1,100 kWh/year
- With a leak diameter of 0.08 in. (2 mm): 4,500 kWh/year
- With a leak diameter of 0.16 in. (4 mm): 11,250 kWh/year

The most common areas for leaks are couplings, hoses, tubes, fittings, pressure regulators, open condensate traps and shut-off valves, pipe joints, disconnects, and thread sealants. Quick-connect fittings always leak and should be avoided. Leaks can make air tools less efficient and adversely affect production, shorten the life of equipment, lead to additional maintenance requirements, and increase unscheduled downtime. Leaks also cause an increase in compressor energy and maintenance costs. However, it is cost-effective to fix leaks, with typical repairs costing $400. In more than one thousand examples of reducing leaks in pipes and equipment, the average payback period was about five months.

Detecting leaks. A simple way to detect large leaks is to apply soapy water to suspect areas, or to use a bag to monitor the velocity of the air filling the bag, although this may be time consuming. In the "bag test," a plastic bag is put up to the leak and used to monitor the velocity of the air filling the bag.

Another simple way to identify leaks is by performing a bleed down test (Bayne 2011). In order to conduct the test, the plant air system is brought to full pressure and then shut down. By recording the system pressure while compressed air is not used anywhere in the plant, any pressure losses can be attributed to existing leaks.

The best way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high-frequency hissing sounds associated with air leaks. After identifying them, leaks should be tracked, repaired, and verified. Leak detection and correction programs should be ongoing efforts.

Case study: Reducing leaks

Bauducco is one of the leading producers of baked products in Brazil. A cleaner production audit revealed that its plant could reduce its electricity use by 350 MWh/year through the detection and reduction of leaks in its compressed air systems. At an investment cost of $22,000, an effort to reduce leaks would save $33,000 per year and pay for itself in only 9 months (International Finance Corporation (IFC) 2012)

Turn off unnecessary compressed air. Equipment that is no longer using compressed air should have the air turned off completely. This can be done using a simple solenoid valve. Check compressed air distribution systems when equipment has been reconfigured to ensure no air is flowing to unused equipment or obsolete parts of the compressed air distribution system.

Modify the system instead of increasing system pressure. For individual applications that require a higher pressure, consider special equipment modifications instead of raising the operating pressure of the whole system. For example:

- use a booster,
- increase a cylinder bore,
- change gear ratios, and
- change operation to off -peak hours.

Use sources other than compressed air Many operations can be accomplished more economically and efficiently using other energy sources. Some industry engineers believe this measure has the largest potential for compressed air energy savings. As shown in Table 8, various options can replace compressed air use (U.S. DOE 2004b)(2004d).

Case study: Replacing compressed air

A U.S. bread plant utilized high-pressure compressed air jets and air bars to clean bun pans after the baking step. Based on findings of a plant energy assessment, the plant has installed high-pressure blowers for pan cleaning to replace this energy-intensive use of compressed air. The measure is expected to reduce plant energy costs by nearly $16,000 per year. At an investment cost of $9,000, the high-pressure blowers will pay for themselves through reduced energy costs in only 7 months (Base Co. 2012).

Table 8. Alternatives for compressed air

Application	Alternative
Cooling electrical cabinets	Air conditioning fans should be used instead of using compressed air vortex tubes.
Flowing high pressure air past an orifice to create a vacuum	A vacuum pump system should be applied instead of compressed air venturi methods.
Cooling, aspirating, agitating, mixing, or package inflating	Blowers
Cleaning parts or removing debris	Brushes, blowers, or vacuum pump systems or nozzles that are more efficient
Moving parts	Blowers, electric actuators, or hydraulics
Blowguns, air lances, and agitation	Low-pressure air or mechanical actions
Tools or actuators	Consider efficient electric motors. Some sources, however, have reported that motors can have less precision, shorter lives, and lack safety. In these cases, using compressed air may be a better choice.

Note: Numerous case studies across industry estimate an average payback period of 11 months for replacing compressed air with other applications.

Manage the load. Because of the large amount of energy consumed by compressors, whether in full operation or not, partial load operation should be avoided. For example, unloaded rotary screw compressors still consume 15% to 35% of full-load power while delivering no useful work (U.S. DOE 2003). Centrifugal compressors are cost effective when operated at high loads.

Use air at lowest possible pressure. Although system pressure may be higher, air used for a particular application should be at the lowest pressure needed. For compressed air systems in the range of 100 psig, having 30-50% unregulated air (leaks, open blowing etc.), a 2 psi decrease in pressure will result in 1.6-2.0% energy savings (U.S. DOE 2003). One plant audit of a U.S. bakery estimated the payback period for this measure at around 10 months (Base Co. 2012).

Minimize pressure drop in distribution system design. An excessive pressure drop results in poor system performance and excessive energy consumption. Flow restrictions of any type, such as an obstruction or roughness, require operating pressures to be higher than necessary. Flow resistance increases pressure (and associated compressor energy use) by 1% for each 2 psi of pressure rise. The highest pressure drops are usually found at the points of use. These include:

- undersized or leaking hoses
- tubes
- disconnects
- filters
- regulators
- valves
- nozzles and lubricators (demand side)
- air/lubricant separators on lubricated rotary compressors and aftercoolers
- moisture separators
- dryers, and filters.

Minimizing pressure drop requires a systems approach in design and maintenance. Select air treatment components with the lowest possible pressure drop at the specified maximum operating conditions and best performance. Follow manufacturers' recommendations for maintenance, particularly for air filtering and drying equipment, which can have damaging moisture effects like pipe corrosion. Finally, minimize the distance that air travels through the distribution system (U.S. DOE 2003).

Reduce inlet air temperature. If airflow is kept constant, reducing the inlet air temperature reduces energy used by the compressor. In many plants, it is possible to reduce inlet air temperature to the compressor by taking suction from outside the building. As a rule of thumb, each 5°F (3°C) will save 1% compressor energy. A payback period may be between one to five years (CADDET 1997) (Parekh 2000).

Controls. The total air requirement is the sum of the average air consumption for each tool on the system, so a control strategy should focus on shutting off unneeded tools. This can mean shutting off compressors or not turning on additional compressors until needed. All compressors that are on should be running at full load, except for one, which should handle trim duty.

To determine proper control systems, assess compressed air requirements over time, establishing a load profile. When demand is less than peak, the most efficient strategy is to use multiple smaller compressors with sequencing controls. Facilities with a flat load profile can use simpler control strategies.

Control loop positioning is also important; reducing and controlling the system pressure downstream of the primary receiver can reduce energy consumption up to 10% to 12% (Radgen and Blaustein 2001). An excellent review of compressor controls can be found in Compressed Air Challenge® Best Practices for Compressed Air Systems (Second Edition) (Scales and McCulloch 2007). Common control strategies for compressed air systems include:

Case study: Compressor controls

Golden Temple of Oregon recently installed a variable speed control-based air compressor system in its cereal flake extrusion facility. The benefits of variable speed control included (FIRE 2005b):

• Verified annual energy savings of 157 MWh (30% of base energy use);

• Less maintenance with only one compressor instead of five; and

• Reduced compressor and motor wear due to soft starting/stopping and reduced revolutions.

- *Start/stop* (on/off) is the simplest control strategy and can be applied to small reciprocating or rotary screw compressors. Start/stop controls turn the motor driving the compressor on or off in response to the machine's discharge pressure. These controls are used for applications with very low duty cycles. Applications with frequent cycling will cause the motor to overheat. Typical payback period for start/stop controls is one to two years.
- *Load/unload control*, or *constant speed control,* allows the motor to run continuously but unloads the compressor when the discharge pressure is adequate. In most cases, unloaded rotary screw compressors still consume 15% to 35% of full-load power when fully

unloaded, while delivering no useful work. Therefore, load/unload controls can be inefficient and require ample primary receiver volume.

- *Modulating or throttling controls* allow the output of a compressor to be varied to meet flow requirements by closing down the inlet valve and restricting inlet air to the compressor. Throttling controls are applied to centrifugal and rotary screw compressors. Changing the compressor control to a variable speed control can save up to 8% of electricity and electricity cost per year.
- *Multi-step or part-load controls* can operate in two or more partially loaded conditions. Output pressures can be closely controlled without requiring the compressor to start/stop or load/unload.
- *System controls* work on multiple compressors. Single master sequencing system controls take individual compressor capacities on and offline in response to monitored system pressure demand and shut down any compressors running unnecessarily. System controls for multiple compressors typically offer a higher efficiency than individual compressor controls.

Properly size regulators. Regulators can provide the largest energy savings in compressed air systems. By properly sizing regulators, compressed air that is otherwise wasted as excess air will be saved. Specify pressure regulators that close when failing.

Size pipe diameter correctly. Inadequate pipe sizing can cause pressure losses, increase leaks, and increase generating costs. Pipes must be sized correctly for optimal performance or resized to fit the current compressor system. Increasing pipe diameters typically reduces compressed air system energy consumption by 3% (Radgen and Blaustein 2001). Further savings can be realized by ensuring other system components (e.g., filters, fittings, and hoses) are properly sized.

Implement system improvements. Adding additional compressors should be considered only after a complete system evaluation. Implementing some of the measures discussed in this section can reduce air demand considerably, negating the need to purchase additional compressors. The Compressed Air Challenge© (CAC 2012) offers free web-based guidance for selecting the right integrated service provider, as well as guidelines defining walk-through evaluations, system assessments, and fully instrumented system audits.

Recover heat for water preheating. As much as 80% to 93% of the electrical energy used by an industrial air compressor is converted into heat. In many cases, a heat recovery unit can recover 50% to 90% of the available thermal energy for the following applications:

- Space heating
- Water heating
- Makeup air heating
- Boiler makeup water preheating

Case study: Compressor heat recovery

A Unilever Canada plant recovered heat from its compressors to completely heat its loading docks. The simple payback period for the project was about 2.5 years (CIPEC 2008).

Payback periods are typically less than one year.). It has been estimated that approximately 50,000 Btu/hour of recoverable heat is available for each 100 cfm of compressor capacity (U.S. DOE 2003).

Heat recovery for space heating is not as common with water-cooled compressors because an extra stage of heat exchange is required and the temperature of the available heat is somewhat low. However, with large water-cooled compressors, recovery efficiencies of 50% to 60% are typical (U.S. DOE 2003).

5.1.5 Pumps

Pumps are particularly important pieces of motor-driven equipment in many small- and medium-sized plants. They are used extensively to pressurize and transport water in cleaning and wastewater handling operations; for transporting liquid streams between processes; and for circulating liquids within processes. The basic components in a pump system are pumps, drive motors, piping networks, valves, and system controls. Some of the most significant energy efficiency measures applicable to these components and to pump systems as a whole are described below. The U.S. DOE's Industrial Technologies Program provides a variety of resources for improving the efficiency of industrial pump systems, which can be consulted for more detailed information on many of the measures presented in this section. The U.S. DOE's *Improving Pumping System Performance: A Sourcebook for Industry* is a particularly helpful resource (U.S. DOE 2006b). Also, many tips, tools, and industrial case studies on pumping system efficiency can be found at the U.S. DOE's *BestPractices Website* (U.S. DOE 2012d).

Take a systems approach when assessing pump energy efficiency improvement opportunities within a facility. Even if an individual pump is operating efficiently, if it is generating more flow than the system requires for a given application, it is wasting energy and money. Assess both individual pump efficiencies and how well the various pump system end uses are being served by its pumps.

A pump's initial capital cost is typically only a small fraction of its total life cycle costs. In general, maintenance and energy costs represent by far the most significant fraction of a pump's total life cycle costs. In some cases, energy costs can account for up to 90% of the total cost of owning a pump (U.S. DOE 2001a). So, when choosing pumping equipment, base your decision on projected energy and maintenance costs rather than on initial capital costs alone.

The Pump Systems Matter™ (Hydraulic Institute 2012) program conceived by the Hydraulic Institute, provides detailed information on improving the performance of pump systems. The most important opportunities for increasing efficiency are discussed below.

Implement a pump system maintenance program. Inadequate maintenance can lower pump system efficiency, cause pumps to wear out more quickly, and increase pumping energy costs. Implementing a pump system maintenance program will help you avoid these problems by keeping pumps running optimally. Improved pump system maintenance can lead to pump system energy savings from 2% to 7% (Xenergy 1998).

A solid pump system maintenance program will generally include the following tasks (U.S. DOE 2006b):

- Place worn impellers, especially in caustic or semi-solid applications.
- Inspect and repair bearings.
- Replace bearing lubrication annually or semiannually.
- Inspect and replace packing seals. Allowable leakage from packing seals is usually between 2 to 60 drops per minute.
- Inspect and replace mechanical seals. Allowable leakage is typically 1 to 4 drops per minute.
- Replace wear ring and impeller. Pump efficiency degrades by 1% to 6% for impellers less than the maximum diameter and with increased wear ring clearances.
- Check pump/motor alignment.
- Inspect motor condition, including the motor winding insulation.

Monitor pump systems. Monitoring, combined with a proper maintenance program, will help detect pump system problems before they escalate into major performance issues or equipment repairs. Monitoring can be done manually on a periodic basis (for example, performing regular bearing oil analyses to detect bearing wear, or using infrared scanning to detect excessive pump heat), or it can be performed continuously using sensor networks and data analysis software (such as using accelerometers to detect abnormal system vibrations) (U.S. DOE 2006b). Monitoring can help keep pump systems running efficiently by detecting system blockages, impeller damage, inadequate suction, clogged or gas-filled pumps or pipes, pump wear, and if pump clearances need to be adjusted.

In general, a good pump monitoring program should include the following aspects:

- Wear monitoring.
- Vibration analysis.
- Pressure and flow monitoring.
- Current or power monitoring.
- Monitoring of differential head and temperature rise across pumps (also known as thermodynamic monitoring).
- Distribution system inspection for scaling or contaminant build-up.

Reduce pump demand. An important component of the systems approach is to minimize pump demand by better matching pump requirements to end-use loads. Two effective strategies for reducing pump demand are (1) the use of holding tanks, and (2) the elimination of bypass loops.

Holding tanks can be used to equalize pump flows over a production cycle, which can allow for more efficient operation of pumps at reduced speeds and lead to energy savings of up to 10% to 20% (Xenergy 1998). Holding tanks can also reduce the need to add pump capacity.

The elimination of bypass loops and other unnecessary flows can produce similar energy savings, as can lowering process static pressures, minimizing elevation rises in the piping system, and lowering spray nozzle velocities.

Install controls. Control systems can increase the energy efficiency of a pump system by shutting off pumps automatically when demand is reduced or by putting pumps on standby at reduced loads until demand increases.

Install high efficiency pumps. It has been estimated that up to 16% of pumps in use in U.S. industry are more than 20 years old (Xenergy 1998). Considering that a pump's efficiency may degrade by 10% to 25% over the course of its life, the replacement of aging pumps can lead to significant energy savings. The installation of newer, higher-efficiency pumps typically leads to pump system energy savings of 2% to 10% (Elliott 1994).

A number of high-efficiency pumps are available for specific pressure head and flow rate capacity requirements. Choosing the right pump often saves both operating costs and capital costs. For a given duty, selecting a pump that runs at the highest speed suitable for the application will generally result in a more efficient selection as well as the lowest initial cost (U.S. DOE 2001a).

A number of high efficiency pumps are available for specific pressure head and flow rate capacity requirements. Choosing the right pump saves both operating costs and capital costs. For a given duty, selecting a pump that runs at the highest speed suitable for the application will generally result in a more efficient selection, as well as the lowest initial cost (U.S. DOE 2001b).

Properly size pumps. Pumps that are oversized for a particular application consume more energy than is truly necessary. Replacing oversized pumps with pumps that are properly sized can often reduce the electricity use of a pumping system by 15% to 25% (Xenergy 1998). Where peak loads can be reduced through improvements to pump system design or operation (e.g., via the use of holding tanks), pump size can also be reduced. If a pump is dramatically oversized, often its speed can be reduced with gear or belt drives or a slower speed motor. The typical payback period for the above strategies can be less than one year (Galitsky et al. 2005).

Use multiple pumps for variable loads. The use of multiple pumps installed in parallel can be a cost-effective and energy-efficient solution for pump systems with variable loads. Parallel pumps offer redundancy and increased reliability, and can often reduce pump system electricity use by 10% to 50% for highly variable loads. Parallel pump arrangements often consist of a large pump, which operates during periods of peak demand, and a small (or "pony") pump, which operates under normal, more steady-state conditions (U.S. DOE 2006b). Because the pony pump is sized for normal system operation, this configuration operates more efficiently than a system that relies on a large pump to handle loads far below its optimum capacity.

Consider trimming impellers. *Impeller trimming* is machining to reduce an impeller's diameter. This reduces the energy added by the pump to the system fluid. According to the U.S. DOE (2006a), one should consider trimming an impeller when any of these conditions occur:

- Many system bypass valves are open, indicating that excess flow is available to system equipment.
- Excessive throttling is needed to control flow through the system or process.
- High levels of noise or vibration indicate excessive flow.
- A pump is operating far from its design point.

Trimming an impeller is slightly less effective than buying a smaller impeller from the pump manufacturer, but it can be useful when an impeller at the next available smaller size would be too small for the given pump load. The energy savings associated with impeller trimming are dependent upon pump power, system flow, and system head, but are roughly proportional to the cube of the diameter reduction (U.S. DOE 2006b). An additional benefit of impeller trimming is a decrease in pump operating and maintenance costs.

Avoid throttling valves. Throttling valves and bypass loops are indications of oversized pumps. They also indicate the inability of the pump system design to accommodate load variations efficiently, so they should always be avoided (Tutterow, Casada, and McKane 2000). Pump demand reduction, controls, impeller trimming, and multiple pump strategies (all previously discussed) are preferred over throttling valves.

Replace drive belts. According to inventory data of U.S. industrial pumps, up to 4% of pumps are equipped with V-belt drives (Xenergy 1998). Many of these V-belt drives can be replaced with direct couplings, which are estimated to lead to energy savings of around 1%.

Properly size pipes. Pipes that are too small for the required flow velocity can significantly increase the amount of energy required for pumping, in much the same way that drinking a beverage through a small straw requires a greater amount of suction. Where possible, pipe diameters can be increased to reduce pumping energy requirements, but the energy savings due to increased pipe diameters must be balanced with increased costs for piping system components. Increasing pipe diameters will likely only be cost effective during greater pump system retrofit projects. Xenergy (1998) estimate typical industrial energy savings in the 5% to 20% range for this measure.

Case study: Variable speed pumps

An energy audit revealed that a U.S. bread plant could reduce its electricity use by 58 MWh/year through the installation of a variable speed drive on its chilled glycol pumps. At a cost of $13,000, the new drive would save $7,400 per year and pay for itself in around 1.7 years (BASE 2012).

Consider adjustable-speed drives (ASDs). Pumps that experience highly variable demand conditions are often good candidates for ASDs. As pump system demand changes, ASDs adjust the pump speed to meet this demand, thereby saving energy that would otherwise be lost to throttling or bypassing. The resulting energy and maintenance cost savings can often justify the investment costs for the ASD. However, ASDs are not practical for all pump system applications—for example, those that operate at high static head and those that operate for extended periods under low-flow conditions (U.S. DOE 2006b).

5.1.6 Hot Water and Steam Systems

Hot water and steam are significant energy users in many U.S. baking plants. The size and use of modern systems vary greatly; however, steam systems do follow a typical pattern, as illustrated in Figure 4. Treated cold feed water is fed to the boiler, where it is heated to form steam. Chemical treatment of the feed water removes many impurities that would otherwise collect on boiler walls, but some remain, so the water is periodically purged from the boiler in a process known as *blowdown.* The generated steam travels along distribution pipes to the process where the heat will be used. If the process requires lower pressure steam, the steam from the boiler may be passed through a pressure reduction valve before final use. As the steam is used to heat processes, and even as it travels through the distribution system to get there, the steam cools and some is condensed. This condensate is removed by a steam trap, which passes the condensate through but blocks passage of the steam. The condensate can be recirculated to the boiler, thus recovering some heat and reducing the need for fresh treated feed water. The recovery of condensate and blowdown also reduces the costs of boiler feed water treatment.

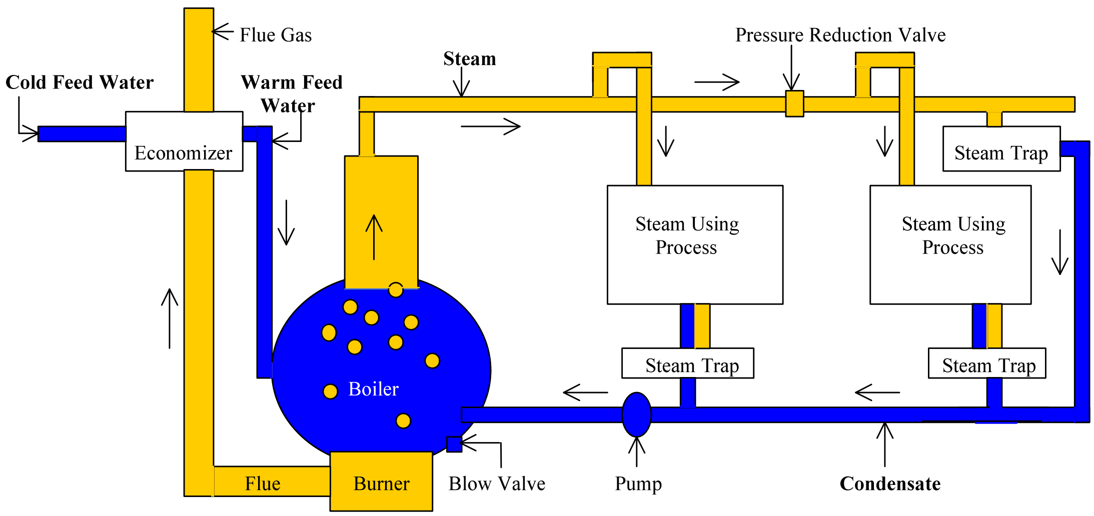

Figure 4. Simplified schematic of a steam production and distribution system.

Whatever the use or the source of the steam, efficiency improvements in steam generation, distribution, and end use are possible. According to the U.S. DOE, a typical industrial steam system assessment can identify potential energy use and cost savings of 10% to 15% per year (U.S. DOE 2006d).

Take a system approach in evaluating steam systems. First, identify where and how steam is used and then identify the efficiencies with which it is used, because often this can result in the largest savings. The U.S. DOE provides a variety of resources for improving industrial steam system efficiency, which can be consulted for more detailed information on many of the measures presented in this section. The U.S. DOE's *Improving Steam System Performance, A Sourcebook for Industry* is a particularly helpful resource (U.S. DOE 2004c).

Because steam, like any other secondary energy carrier, is expensive to produce and supply, its use should be carefully considered and evaluated against other options. Often steam is generated at higher pressures than needed or in larger volumes than needed at a particular time. These inefficiencies may lead steam systems to let down steam to a lower pressure or to vent it to the atmosphere. Thus, evaluate the steam system on the use of appropriate pressure levels and production schedules.

If it is not possible to reduce the steam generation pressure, it may still be possible to recover the energy through a turbo expander or back-pressure steam turbine. Many systems may produce steam at higher pressures, to allow for the efficient cogeneration of power and heat through the use of back-pressure turbines. Excess steam generation can be reduced through improved process integration and improved management of steam flows in the industry.

The normal replacement investment cycle might offer opportunities to change to more energy-efficient steam systems.

5.1.6.1 Boiler energy efficiency measures

The boiler energy efficiency measures presented below focus primarily on improved process control, reduced heat loss, and improved heat recovery. When new boiler systems are needed, they should be designed and installed in a custom configuration that meets a particular plant's needs. Pre-designed boilers often cannot be fine-tuned to meet the unique steam generation and distribution system requirements of a specific plant in the most efficient manner (Ganapathy 1994).

Control boiler processes. Flue gas monitors maintain optimum flame temperature and monitor carbon monoxide (CO), oxygen, and smoke. The oxygen content of the exhaust gas is a combination of excess air (which is deliberately introduced to improve safety or reduce emissions) and air infiltration. By combining an oxygen monitor with an intake airflow monitor, it is possible to detect even small levels of air infiltration.

A small 1% air infiltration will result in 20% higher oxygen readings. A higher CO or smoke content in the exhaust gas is a sign that there is insufficient air to complete fuel burning. Using a combination of CO and oxygen readings, it is possible to optimize the fuel/air mixture for high flame temperature (and thus the best energy efficiency) and lower air pollutant emissions.

Typically, this measure is financially attractive only for large boilers, because smaller boilers often will not make up the initial capital cost as easily. Case studies indicate that the average payback period for this measure is about 1.7 years (IAC 2011).

Reduce flue gas quantities using visual inspection. Excessive flue gas can be released from leaks in the boiler and/or in the flue. These leaks can reduce the heat transferred to the steam and increase pumping requirements. However, such leaks are easily repaired, saving 2% to 5% of the energy formerly used by the boiler (Galitsky et al. 2005).

This measure differs from flue gas monitoring in that it consists of a periodic repair based on visual inspection. The savings from this measure and from flue gas monitoring are not cumulative, as they both address the same losses.

Reduce excess air. When too much excess air is used to burn fuel, energy is wasted, because excessive heat is transferred to the air rather than to the steam. Air slightly in excess of the ideal stoichiometric fuel-to-air ratio (that is, the amount of inlet air per unit of fuel combusted) is required for safety and to reduce nitrogen oxide (NO_x) emissions, but approximately 15% excess air is generally adequate. Most industrial boilers already operate at 15% excess air or lower, and thus this measure may not be widely applicable (Zeitz 1997). However, if a boiler is using too much excess air, numerous industrial case studies indicate that the payback period for this measure is less than 1 year (IAC 2011).

Properly size boiler systems. Designing the boiler system to operate at the proper steam pressure can save energy by reducing stack temperature, piping radiation losses, and leaks in steam traps. In a Canadian study of 30 boiler plants, savings from this measure ranged from 3% to 8% of total boiler fuel consumption (Griffin 2000). Costs and savings will depend heavily on the current boiler system utilization at individual plants.

Improve boiler insulation. It is possible to use new materials, such as ceramic fibers, that both insulate better and have a lower heat capacity (thus allowing for more rapid heating). Savings of 6% to 26% can be achieved if improved insulation is combined with improved heater circuit controls. Due to the lower heat capacity of new materials, the output temperature of boilers can be more vulnerable to temperature fluctuations in the heating elements (Caffal 1995). Improved boiler process control is therefore often required in tandem with new insulation to maintain the desired output temperature range

Case study: Burner maintenance

Bauducco is one of the leading producers of baked products in Brazil. A cleaner production audit revealed that its plant could reduce its natural gas costs by $95,000 per year through burner maintenance and optimization efforts. At an investment cost of $18,000, this effort would pay for itself in only 3 months (IFC 2012).

Implement a boiler maintenance program. A simple maintenance program ensures that all boiler components are operating at peak performance and can result in substantial savings. In the absence of a good maintenance system, burners and condensate return systems can wear or get out of adjustment. These factors can end up costing a steam system up to 30% of its initial efficiency over two to three years (Galitsky et al. 2005). For more tips on maintaining boilers, see the Boiler Tune-Up Guide for Natural Gas and Light Fuel Oil Operation (Harrell 2005).

Control fouling on the fire side of boiler tubes and scaling on the water side of boilers. Fouling and scaling are more of a problem with coal-fed boilers than natural gas or oil-fed boilers. Boilers that burn solid fuels like coal should be checked more often because they have a higher fouling tendency than liquid fuel boilers do. Tests of various Canadian boilers show that a fire side soot layer of 0.03 inches (0.8 mm) reduces heat transfer by 9.5%, while a 0.18 inch (4.5 mm) soot layer reduces heat transfer by 69% (CIPEC 2001). For waterside scaling, 0.04 inches (1 mm) of buildup can increase fuel consumption by 2% (CIPEC 2001).

Case study: Feedwater preheating

A U.S. bread plant has two ovens with exhaust temperatures of about 650 °F. An energy assessment recommended installation of a heat exchanger on the oven exhaust stack to recover this waste heat and use it to preheat boiler feedwater. This measure was estimated to save about 17,500 therms of natural gas per year in the plant's boilers. At an investment cost of $25,000, the feedwater preheating system would pay for itself through reduced natural gas costs in only 2.2 years (Base 2012).

Recover flue gas heat. Heat recovery from flue gas is often the best opportunity for heat recovery in steam systems, as it can be used to preheat boiler feed water in an economizer. While this measure is fairly common in large boilers, there is still room for more heat recovery. The limiting factor is that the economizer wall temperature must not drop below the dew point of acids contained in the flue gas (such as sulfuric acid derived from sulfur-containing fossil fuels). Traditionally, this has been accomplished by keeping the flue gases exiting the economizer at a temperature significantly above the acid dew point. In fact, the economizer wall temperature is much more dependent on feed water temperature than on flue gas temperature because of the high heat transfer coefficient of water. As a result, it makes more sense to preheat feed water to close to the acid dew point before it enters the economizer. This approach allows the economizer to be designed so that exiting flue gas is just above the acid dew point. Typically, 1% of fuel use is saved for every 45°F (25°C) reduction in exhaust gas temperature (Ganapathy 1994).

Return condensate to the boiler. Reusing hot condensate in boilers saves energy, reduces the need for treated boiler feed water, and reclaims water at up to 100°C (212°F) of sensible heat.

Typically, fresh feed water must be treated to remove solids that might accumulate in the boiler; thus, returning condensate (which has already been treated) to a boiler can substantially reduce the amount of purchased chemical required to accomplish this treatment. This measure can save substantial energy costs and, purchased chemicals costs often makes building a return piping system attractive. Payback period will depend on the plant layout, but can vary between two and three years.

Recover blowdown steam. When water is blown from a high-pressure boiler tank, the pressure reduction often produces substantial amounts of steam. This steam is typically low grade, but can be used for space heating and feed water preheating. The recovery of blowdown steam can save about 1% of boiler fuel use in small boilers (Galitsky et al. 2005). In addition to energy savings, blowdown steam recovery may reduce the potential for corrosion damage in steam system piping.

Replace old boilers. Substantial efficiency gains can often be achieved by replacing old boilers with new, higher-efficiency models. In particular, replacing inefficient coal-fired boilers with natural gas-fired boilers is a sound strategy for reducing both boiler fuel costs and air pollutant emissions.

5.1.6.2 Steam distribution system energy efficiency measures

Steam and hot water distribution systems are often quite extensive and can be major sources of energy losses. Energy efficiency improvements to steam distribution systems primarily focus on reducing heat losses throughout the system and recovering useful heat from the system wherever feasible. The following measures are some of the most significant opportunities for saving energy in industrial steam distribution systems.

Improve distribution system insulation. Using more insulating material or using the best type of insulation material for the application can save energy in steam systems. Crucial factors in choosing insulating material include low thermal conductivity, dimensional stability under temperature change, resistance to water absorption, and resistance to combustion. Other characteristics of insulating material may also be important depending on the application, such as tolerance of large temperature variations, tolerance of system vibrations, and adequate compressive strength where the insulation is load bearing (Baen and Barth 1994). Industrial plant case studies indicate that the payback period for improved insulation is typically less than one year (IAC 2011).

Maintain distribution system insulation. It is often found that after heat distribution systems have undergone some form of repair, the insulation is not replaced. In addition, some types of insulation can become brittle or rot over time. A regular inspection and maintenance system for insulation can save energy.

Improve steam traps. Modern thermostatic element steam traps can reduce energy use while improving reliability (Alesson 1995). The main efficiency advantages are that these traps:

- open when the temperature is very close to that of saturated steam (within 4°F or 2°C),
- purge non-condensable gases after each opening, and
- are open on startup to allow a fast steam system warm-up.

These traps also have the advantage of being highly reliable and useable for a range of steam pressures.

Maintain steam traps. A simple program of checking steam traps to ensure that they are operating properly can save significant amounts of energy for very little money. In the absence of a steam trap maintenance program, it is common to find up to 15% to 20% of steam traps malfunctioning in a steam distribution system (Jaber 2005). Energy savings for a regular system of steam trap checks and follow-up maintenance is conservatively estimated at 10% (Bloss, Bockwinkel, and Rivers 1997, Jones 1997). Although this measure offers quick payback, it is often not implemented because maintenance and energy costs are generally separately budgeted. In addition to energy and cost savings, properly functioning steam traps reduce the risk of corrosion in the steam distribution system.

Monitor steam traps. Attaching automated monitors to steam traps in conjunction with a maintenance program can save even more energy without significantly adding costs. This measure is an improvement over steam trap maintenance alone, because it gives quicker notice of steam trap failure and can detect when a steam trap is not performing at peak efficiency. This strategy can provide an additional 5% in energy savings compared to steam trap maintenance alone, at a payback period of about one year. Systems that can implement steam trap maintenance are also likely to be able to implement automatic monitoring (Galitsky et al. 2005).

Repair leaks. As with steam traps, steam distribution piping networks often have leaks that can go undetected without a regular inspection and maintenance program. The U.S. DOE estimates that repairing leaks in an industrial steam distribution system will lead to energy savings of about 5% to 10% (U.S. DOE 2006c).

Recover flash steam. When a steam trap purges condensate from a pressurized steam distribution system to ambient pressure, flash steam is produced. As with flash steam produced by boiler blow down, steam trap flash steam can be recovered and used for low grade facility applications, such as space heating or feed water preheating (Johnston 1995). The potential for this measure is site dependent, as its cost effectiveness depends on whether or not areas where low-grade heat is useful are located close to steam traps. Where feasible, this measure can be easy to implement and can save considerable amounts of energy.

5.1.7 Refrigeration Systems

Refrigeration systems are a significant consumer of electrical energy in facilities that produce frozen products or employ cold storage.

There are four primary components to the typical refrigeration system: (1) the compressor, (2) the condenser, (3) the expansion valve, and (4) the evaporator. In the first stage of the refrigeration cycle, refrigerant enters the compressor as a low pressure gas and is pressurized by the compressor into a hot, high pressure gas. The high pressure gas leaves the compressor and is circulated to the condenser. In the condenser, the high pressure gas is cooled via a heat exchanger with a cooling medium (typically ambient air), which causes it to condense into a hot liquid. The hot liquid refrigerant then proceeds through an expansion valve, which decreases the pressure of the refrigerant, causing it to cool. The cool refrigerant is then circulated to an evaporator. In the evaporator, the refrigerant accepts heat from its surroundings, causing it to vaporize into a low pressure gaseous state. In direct expansion evaporators, the evaporator coils are in direct contact with the object or fluid that is being refrigerated. In indirect expansion evaporators, the evaporator coils are in contact with a carrier medium, such as water, brine, or glycol, which is then pumped to the object that is being refrigerated. From the evaporator, the low pressure gas is fed back to the compressor, completing the cycle.

Most U.S. industrial refrigeration systems use ammonia as a refrigerant. Some favorable properties that make ammonia the refrigerant of choice include its high latent heat of vaporization, its classification as a non ozone-depleting substance, the fact that it is non-corrosive to iron and steel, and because ammonia leaks can often be easily detected by smell (Singh and Heldman 2001).

This section discusses some of the most significant energy efficiency measures available for industrial refrigeration systems. Measure descriptions are grouped under the following four major categories, based on their applicability: (1) refrigeration system management, (2) cooling load reduction, (3) compressors, and (4) condensers and evaporators.

5.1.7.1 Refrigeration System Management

Good housekeeping. Good housekeeping refers to simple steps that can be taken by all facility personnel on a regular basis to help keep refrigeration systems running properly and efficiently. Such actions include the following (Carbon Trust 2000b):

- Reporting and repairing any pipes that are vibrating.
- Making sure the control settings for the refrigeration system are easy to find and interpret for ease of system tuning and adjustment.
- Keeping the doors to cold storage areas closed whenever possible.
- Making sure that cold storage areas are not cooled to a lower temperature than is truly needed (refrigeration system energy use will increase by 1% to 3% for every degree (Fahrenheit) of additional cooling).

- Making sure that products are not stacked directly under or in front of evaporators in cold storage units.
- Minimizing other heat sources (such as lights and forklifts) in cold storage areas, which produce heat that will have to be removed by the refrigeration system.
- Reporting the formation of ice on cold storage area floors and walls. Ice indicates that a lot of air is entering the cold storage area, which carries moisture that gives off heat as it freezes, adding to the refrigeration load.
- Switching off system pumps and fans (such as those used for circulating cold air, chilled water, or anti-freeze) when not required. Pumps and fans can add significant heat loads to the refrigeration system during operation.
- Reporting and repairing damage to refrigeration system pipe insulation.
- Regularly checking compressor oil levels to ensure proper lubrication.
- Reporting and repairing any refrigerant leaks.

Monitoring system performance. Monitoring systems can help detect refrigeration system performance issues before they become major problems, helping to avoid major repair costs and keeping the system running at optimal efficiency. Monitoring involves the installation of sensors at key points in the refrigeration system, which can be as simple as visual gauges or as advanced as computer-based sensor and control networks. A basic monitoring system should include ongoing measurement and logging of compressor suction and discharge pressures; a drop in suction pressure typically indicates a refrigerant leak, while a rise in discharge pressure can indicate a blocked condenser (Carbon Trust 2000b). Ideally, monitoring systems should also have the ability to provide system and component level information to operating and maintenance staff as well as high-level performance summaries for management. In a review of energy efficiency opportunities for refrigeration systems in wineries, the energy savings associated with the installation of monitoring systems were estimated at 3% (Galitsky et al. 2005).

Ensuring proper refrigerant charge. Low refrigerant charge affects many small direct expansion systems, and, if left unchecked, can lead to significant deteriorations in system performance and energy efficiency over time. Additionally, too much refrigerant charge (i.e., over-charging) can also reduce energy efficiency. Galitsky et al. (2005) report that a low refrigerant charge or over-charging can increase the energy use of direct expansion systems by as much as 20%. Regular monitoring and maintaining of refrigerant charge is therefore critical for ensuring optimal system performance. The refrigerant sight glass should be checked periodically for bubbles (when the system is operating at steady state), which can indicate that refrigerant is leaking somewhere in the system (Carbon Trust 2000b).

Refrigeration system controls. Control systems can help improve the energy efficiency of refrigeration systems by ensuring optimal matching of cooling demand and component loads. Optimal matching is usually done by monitoring the temperature of the space, object, or media that is being cooled and adjusting the operation of key system components to maintain the desired temperature in the most efficient manner.

Another important application of control systems is to ramp down or turn off system components during periods of non-use. For example, automatic switches or ASDs can be used to turn down or off system fans and pumps where feasible, with typical payback periods of one year or less (Carbon Trust 2000b).

The International Institute of Refrigeration recommends avoiding the following control strategies that may compromise system energy efficiency (Pearson 2003):

- Slide valve unloading of oversized screw compressors.
- Hot gas bypass of compressors.
- Throttling valves between evaporators and compressors.
- Evaporator control by starving refrigerant supply.
- Too frequent defrosts.
- Condenser head pressure controls, except when necessary.

Checking for refrigerant contamination. Refrigerants should be periodically checked for contamination such as oil, water, or debris, which can be an indication of system operating and maintenance problems. Galitsky et al. (2005) estimate energy savings attributable to this measure at around 2%.

Efficient piping design. Interconnecting pipes should be designed such that their size and routing minimizes friction and pressure drops (e.g., using the largest diameter pipe that is economical for the system and avoiding excessive bends and fittings), thereby reducing energy losses in the system (Pearson 2003). This measure might only be economical in large retrofit or new system installation projects.

5.1.7.2 Cooling Load Reduction

Piping insulation. Pipes containing cold refrigerant (i.e., pipes between the expansion valve and evaporator) should be properly insulated to minimize heat infiltration. Piping insulation should be checked regularly for cracks or decay and repaired promptly as needed. Galitsky et al. (2005) estimate the typical energy savings attributable to improved piping insulation at 3% with a payback period of less than two years.

Minimizing heat sources in cold storage areas. Sources of heat within cold storage areas such as lights, forklifts, motors, and even personnel, should be minimized because the refrigeration system must remove the additional heat that they produce. For example, it has been estimated that up to 15% of the refrigeration load in cold storage is due to heat from evaporator fans, and that lighting heat can add an additional 10% to the refrigeration load (Carbon Trust 2006). Thus, heat generating equipment should be switched off when not needed. Also, where feasible, product entering the cold storage area should be as close to the desired cold storage temperature as possible (Carbon Trust 2000a). Several industrial case studies have shown a payback period of less than 6 months in food processing plants that have implemented measures to reduce heat sources in cold storage areas (IAC 2011).

Reducing heat infiltration in cold storage areas. The infiltration of warm outside air can be reduced through proper door management and the use of tight sealing doors. Door seals should be inspected regularly, as faulty door seals can increase refrigeration system energy consumption by up to 11% (Carbon Trust 2006). Where strip/walk-in curtains are used, they should be periodically checked to ensure that they are intact and positioned properly. Additionally, doors should always be closed immediately after personnel or forklifts enter and leave the cold storage area; where feasible, doors that close automatically should be considered. In total, the energy losses associated with improper door management in cold storage areas have been estimated at 10% to 20% of the total cooling load (Galitsky et al. 2005). In IAC audits of U.S. food processing plants, those that implemented heat infiltration reduction measures have achieved simple payback periods of less than 6 months (IAC 2011).

Reducing building heat loads. Refrigeration system compressors in poorly ventilated areas surrounded by warm air will run hotter than necessary, which will reduce compressor reliability and energy efficiency. Compressor areas should be adequately ventilated so that cool air is allowed to circulate around the compressor. Similarly, for air-cooled condensers, an ample supply of cool ambient air is necessary to keep condenser temperatures low. Energy efficiency measures aimed at the building structure, such as the use of adequate insulation and reflective roofing materials, can help reduce the heat load on compressors and condensers, helping them to run more efficiently.

Free cooling. Free cooling makes use of outside air for process and building cooling applications when outdoor air conditions are appropriate, which can reduce the load on refrigeration systems. According to Schepp and Nicol (2005), free cooling is suited for locations where many hours are below 40 degrees Fahrenheit, and has led to energy savings of up to 15% in some Canadian facilities. The payback can be immediate where outdoor air makeup ducts and ventilation control systems already exist, but can range from two to four years when building retrofits are required (Schepp and Nicol 2005). Several U.S. food processing plants that have implemented free cooling systems report simple payback periods of less than 4 years (IAC 2011).

Nighttime air cooling is a form of free cooling, in which cooler outside air is allowed into facility and office areas at night to reduce daytime building heat loads.

Optimized air flow pattern. In cold storage areas and blast air units, air flow patterns are often not optimized, creating temperature gradients, dead zones, and by-pass flow patterns, all of which decrease heat transfer efficiency. A simple project to measure air flow rates in different sections of a room or blast air unit can illuminate these dead zones and by-pass flows. Installation of baffles and other air flow enhancers can then be installed to increase heat transfer efficiency.

Case study: Optimized air flow

A study of a Pacific Seafood Group frozen sardines manufacturer found that installing baffles and lowering the ceiling of blast freezers led to an estimated 12% energy savings (Kolbe and Ling 2004).

Case study: Cooling towers

At a food products company in Oakville, Ontario, the air compressor and air dryer consumed significant amounts of municipal water and further released heated water into the sewer, thereby wasting energy. The company installed a cooling tower to cool heated water and recycle it back into the system. The plant reduced annual water consumption by nearly 20,000 tonnes and thereby saved $11,500 per year. The payback period for this measure was 3.7 years (Ontario Centre for Environmental Technology

Cooling towers. Using cooling tower water instead of chilled water can lead to significant energy savings, with a payback period of less than 4 months (IAC 2011). In a cooling tower, circulating warm water is put into contact with an air flow, which evaporates some of the water. The heat lost by evaporation cools the remaining water, which can then be recirculated as a cooling medium (RACCP 2001).

The U.S. DOE (2006c) offers the following guidelines for operating cooling towers at optimal water efficiency:

- Consider using acid treatment (e.g., sulfuric or ascorbic acid), where appropriate. Acids can improve water efficiency by controlling scale buildup created from mineral deposits.
- Install a side stream filtration system that is composed of a rapid sand filter or high-efficiency cartridge filter to cleanse the water. These systems enable the cooling tower to operate more efficiently with less water and chemicals.
- Consider alternative water treatment options such as ozonation or ionization, to reduce water and chemical usage.
- Install automated chemical feed systems on large cooling tower systems (over 100 tons). The automated feed system should control bleed-off by conductivity and add chemicals based on makeup water flow. Automated chemical feed systems minimize water and chemical use while optimizing control against scale, corrosion and biological growth.

5.1.7.3 Compressors

Compressor control systems and scheduling. The compressor is the workhorse of the refrigeration system, and the use of control systems to effectively match compressor loads to cooling demands is often a sound strategy for energy efficiency. Control systems can help compressors operate at optimal efficiency by monitoring and adjusting to system flow conditions and by scheduling the operation of multiple compressors to minimize part-load operation (e.g., running one compressor at 100% rather than two compressors at 50%) (Carbon Trust 2000a).

Floating head pressure control. Floating head pressure control can be a particularly effective control strategy for reducing compressor energy consumption. Floating head pressure control allows compressor head pressures to move up or down with variations in ambient wet-bulb temperature, saving energy compared to fixed head pressure operation. However, additional energy is required for the condenser fan, which must be balanced with compressor energy savings. It is also important not to allow head

Case study: Compressor controls

Rainier Cold Storage, a cold storage warehouse and frozen seafood products company located in Seattle, Washington, used to run its seven refrigeration plant compressors manually before a computer control upgrade in the early 1990s. The company installed controls consisting of sensors and computer software, which automatically modulated compressor discharge and suction pressures to improve the coefficient of performance and to better adjust compressor operation to changes in refrigeration system cooling demand. The upgrade led to annual energy savings of 367,000 kWh as well as reduced operations and maintenance costs through more efficient system operation (CADDET 2004). The reported payback period, which included both electricity bill savings and reduced operations and maintenance costs, was around 2.6 years.

pressure to go too low, as certain system demands (e.g., liquid injection oil cooling or defrosting) might require minimum head pressures (Galitsky et al. 2005). Hackett, Chow, and Ganji (2005) estimate a typical payback period of less than one year for floating head pressure control systems.

Indirect lubricant cooling. Direct injection of refrigerant is an inefficient method for compressor cooling that can decrease the overall efficiency of screw-type compressors by as much as 5% to 10% (ISU 2005). An indirect system is a more efficient option for lubricating and cooling screw-type compressors, in which a heat exchanger is used in conjunction with cooling tower water, a section of an evaporative condenser, or a thermosyphon system to cool compressor lubricant.

Raising system suction pressure. In two-stage compressor systems, a simple way to save energy is to raise the suction pressure and temperature of the low-stage compressor when ambient temperatures decrease. It has been estimated that energy savings of about 8% can be realized in two-stage systems when suction temperatures are raised from -30 °F to -20 °F (ISU 2005).

Adjustable-speed drives (ASDs) on compressor motors. Adjustable-speed drives can be used in conjunction with control systems to better match compressor loads to system cooling requirements. The Industrial Refrigeration Consortium (2004a) reports that ASDs used on compressors below a part-load ratio of about 95% will deliver performance equal to a fixed speed compressor but with lower electricity requirements. However, at near full (i.e., 100%) load, ASDs are approximately 3% less efficient than fixed speed drives due to electrical power losses associated with the ASD controller. Adjustable-speed drives are thus most beneficial for refrigeration systems with large differences between required and installed condenser capacities (ISU 2005). Galitsky et al. (2005) have estimated average refrigeration system energy savings of 10% from the use of ASDs on compressors.

Compressor heat recovery. Where economically feasible, rejected heat can be recovered from compressors and used in other facility applications, such as space heating or water heating.

Dedicating a compressor to defrosting. It has been reported that if one compressor of a large system can be dedicated to running at the

Case study: Adjustable speed drives

As part of a planned expansion for its dairy facility in Portland, Oregon, WestFarm Foods installed a new compressor with a 350 hp ASD, which allowed the remaining system compressors to either be off or working efficiently at 100% load. Other upgrades included new refrigeration system controls and ASDs on the system's evaporator fans. The total system upgrade reduced annual refrigeration system energy consumption by nearly 40% and annual operating costs by around $75,000 (Cascade 2007). At an investment cost of $310,000, the payback period was estimated at roughly four years; however, energy efficiency investment incentives from Portland General Electric (the local utility company) as well as a 35% tax credit from the Oregon Department of Energy helped reduce the final payback to around one year.

pressure needed for the defrost cycle, while the other compressors can be run at lower system pressures, that the resulting energy savings (due to reduced condensing pressure) can often justify the cost of the dedicated compressor (ISU 2005).

Using an economizer with a single stage, low temperature compressor. The most efficient way to run a low temperature refrigeration unit is to use a two-stage compressor system. However, if the unit is just a single-stage compressor unit, using an economizer is an effective way to improve the energy efficiency of the refrigeration unit (Cascade 2007).

5.1.7.4 Condensers and Evaporators

Keeping condensers clean. Condensers should be checked regularly for dirt, ice buildup, or plugged nozzles, which can reduce heat transfer rates and thus raise the condensing temperature. Furthermore, water-cooled and evaporative condensers should be kept free of hard water or bacterial buildup, which can cause fouling, scaling, and clogging that can also lead to increased condensing temperatures. In general, a one degree Celsius (1.8 degrees Fahrenheit) increase in condensing temperature will increase operating costs by 2% to 4% (Carbon Trust 2000b). Badly corroded condensers should be replaced as soon as possible.

Automatic purging of condensers. Periodic purging of evaporative condensers is needed to remove non-condensable gases (such as air), which can reduce refrigeration system efficiency by increasing system head pressure and impeding condenser heat transfer (CADDET 1996). Automatic purging systems can help refrigeration systems operate efficiently by ensuring purging occurs on a regular basis. Automatic purging systems can also reduce the refrigerant loss and labor costs associated with manual purging.

Case study: Automatic purging

Excel Logistics Ltd., an operator of cold storage facilities in the United Kingdom, installed a five-point automatic refrigeration purging system at their Glasgow, Scotland, facility in 1989. Previously, the company purged its system manually on a weekly basis, which was time consuming and often led to refrigerant loss. The automatic purging system featured computer controls and five different refrigeration system purge points: one at each end of the receiver, one on each of the two condenser outlets, and one on the hot gas line. The company reported that the automatic purging system led to a 15% reduction in compressor energy use and £8,800 ($15,400 in 1991 U.S. dollars) in annual energy savings (CADDET 1996). The simple payback period, including both energy and maintenance cost savings, was 10 months.

Reducing condenser fan use. Sometimes condenser fans are operated continuously, even when the refrigeration system's compressor isn't running. This practice wastes energy. Wherever possible, the operation of condenser fans should be coupled to the operation of the system's compressors to ensure that the fans are only run when needed.

Reducing condensing pressure. This measure is similar to floating head pressure control for compressors (discussed above). To reduce the energy required to compress refrigerant, condensing pressures and temperatures should be set as low as possible. Computer controls can be installed on condensing systems to minimize condensing temperatures and pressures based on ambient wet-bulb temperatures, as well as to optimize the use of condenser fans and water (ISU 2005). Lowering the condensing temperature can reduce compressor energy use by around 2% to 3% for every degree Celsius (1.8 degrees Fahrenheit) of temperature reduction. Several industrial case studies have shown that the simple payback period for reducing condensing pressure is close to zero (IAC 2011).

Use of axial condenser fans. Air-cooled or evaporative condensers generally do not need high-pressure air, and thus axial fans are well suited for this application. Axial fans can reduce compressor fan energy use by up to 50% compared to centrifugal fans (ISU 2005).

Adjustable-speed drives (ASDs) on condenser fans. For refrigeration systems with large differences between installed and operating condensing capacity, the use of ASDs on condenser fans can lead to significant energy savings compared to fixed-speed condenser fans. Prior to installing ASDs, however, it is important to establish the extent to which the condensing pressure can be floated. On systems where floating head operation is stable, ASDs can lower condenser fan energy consumption by up to 40% compared to operating a fixed-speed condenser fan in on/off fashion (IRC 2004b).

Cycling of evaporator fans in cold storage. It is often possible to maintain adequate temperature in cold storage areas without continuously running evaporator fans. Where feasible, evaporator fans can be turned off or ramped down periodically using timers or variable-speed control systems to save electricity while still maintaining proper cold storage temperatures. The cycling of evaporator fans should be managed carefully, however, to avoid stratification (i.e., warm and cool layers of air in the cold storage space) and to ensure that solenoids are cycled properly (for flooded and recirculated evaporators) (Galitsky et al. 2005).

Adjustable-speed drives (ASDs) on evaporator fans. Similar to ASDs on condenser fans, for refrigeration systems with excess evaporator capacity, the installation of ASDs can lead to significant energy savings compared to fixed-speed fans. The cost effectiveness of ASDs, however, depends on the number of hours the evaporator fans can be run under part-load conditions. In an analysis of a -20° Fahrenheit freezer with seven evaporators, the use of ASDs on evaporator fans at a load ratio of 50% required 20% lower power than fixed-speed fans under the same operating conditions (IRC 2004a).

Case study: Cycling of evaporator fans

In 1996, Stahlbush Island Farms, a grower, canner, and freezer of fruits and vegetables in Corvalis, Oregon, installed timers to cycle the evaporator fans of its cold storage unit. Prior to the installation of the timers, evaporator fans were run close to 24 hours per day. By cycling the evaporator fans, the company was able to save around 133,000 kWh of electricity per year because the fans ran for fewer hours and the fan motors released less heat into the cold storage unit (ODEQ 1996). The annual savings were estimated at $4,500 and, with a one-time implementation cost of $1,000, the simple payback period was around three months.

The U.S. DOE has supported the development of a simple evaporator fan controller for medium temperature (28° F to 40° F) walk-in refrigeration units, which is capable of varying fan speed is reported to reduce evaporator and compressor energy consumption by 30% to 50% (U.S. DOE 2001e). The controller regulates the speed of evaporator fan motors to better match cooling demands in the refrigeration cycle. The U.S. DOE estimates typical payback periods of one to two years. As of 2000, the controller had been installed in 300 refrigeration units and had led to cumulative energy savings of around $80,000. According to BC Hydro (2004), evaporator fan controllers are not good candidates for freezers that run under 28° Fahrenheit, have compressors that run continuously, have evaporator fans that run on poly-phase power, and have evaporator fans of types other than shaded-pole and permanent-split-capacitor.

Demand defrost. Evaporators should be defrosted only when necessary, as opposed to on timed schedules where defrosting occurs regardless of need. Defrosting cycles should ideally be based on coil pressure readings, where an increase in pressure drop indicates that frost is present on the coils (which reduces system efficiency) and that defrosting is necessary (ISU 2005).

Water defrosting. Water defrosting is said to be more efficient than hot gas defrosting (a common method of defrosting in which hot refrigerant gas is cycled through the system) (ISU 2005). In water defrosting, water is sprayed manually over the evaporator coils to remove frost. However, water defrosting must be managed properly to ensure that the water does not freeze on the evaporator coils.

5.1.8 Self Generation

Self generation (e.g., co-generation, tri-generation, or renewable energy systems) can be an attractive option for many facilities for reducing the energy intensity of utilities services. This section provides a brief overview of several self-generation measures applicable to the U.S. commercial baking industry.

Combined heat and power (CHP). For baking plants that have simultaneous requirements for process heat, steam, and electricity, the use of CHP systems may be able to save energy and reduce pollution. Combined heat and power plants are significantly more efficient than standard power plants because they take advantage of waste heat. In addition, electricity transmission losses are minimized when CHP systems are located at or near the facility.

Often, utility companies will work with individual companies to develop CHP systems for their facilities. In many cases, the utility company will own and operate the facility's CHP system, allowing dairy processors to avoid the capital expenditures associated with CHP projects while reaping the benefits of a more energy-efficient source of heat and electricity. In addition to energy savings, CHP systems also have comparable or better availability of service than utility generation.

Many large-scale CHP systems use steam turbines. Switching to natural gas-based systems is likely to improve the power output and efficiency of the CHP system, due to increased power production capability. Although the overall system efficiency of a steam turbine-based CHP system (80% HHV) is higher than that of a gas turbine-based CHP system (74% HHV), the electrical efficiency of a gas turbine-based CHP system is superior (27% to 37% for typical industrial scale gas turbines). Furthermore, modern gas-based CHP systems have low maintenance costs and will reduce emissions of NOx, SO_2, CO_2, and particulate matter from power generation considerably, especially when replacing a coal-fired boiler (Energy Nexus Group 2002a, b).

In general, the energy savings of replacing a traditional system (i.e., a system using boiler-based steam and grid-based electricity) with a standard gas turbine-based CHP unit is estimated at 20%-30% (Galitsky et al. 2005). However, savings may be greater when replacing older or less maintained boilers.

Combined cycles (combining a gas turbine and a back-pressure steam turbine) offer flexibility for power and steam production at larger sites, and potentially at smaller sites as well. However, combined cycles are generally less attractive for smaller sites due to the high capital costs of the steam turbine. For larger sites, combined cycles may be an attractive option, depending on natural gas and electricity prices.

Case studies: Combined heat and power

Schneider Foods of Kitchener, Ontario, discovered in an energy audit that a natural gas cogeneration unit could provide significant cost savings. With a payback period of 4 years, the plant estimated an annual savings of $1.5 million (CIPEC 2002).

Similarly, Bauducco (a producer of baked products in Brazil) found through a cleaner production audit that it might save nearly $300,000 per year in energy costs by investing in a gas turbine combined heat and power unit. At an investment cost of $740,000, the unit would pay for itself in only 2.5 years (IFC 2012).

Steam-injected gas turbines (STIG) can absorb excess steam (e.g., due to seasonally reduced heating needs) to boost power production by injecting steam into the turbine. The size of typical STIGs starts around 5 MW. STIGs are found in various industries and applications, especially in Japan and Europe, as well as in the United States (for example, International Power Technology installed STIGs at Sunkist Growers in Ontario, California, in 1985) (Bailey and Worrell 1995). A STIG uses the exhaust heat from a combustion turbine to turn water into high-pressure steam, which is then fed back into the combustion chamber to mix with the combustion gas. The advantages of this system are (Wilis and Scott 2000):

- The added mass flow of steam through the turbine increases power by about 33%.
- The machinery involved is simplified by eliminating the additional turbine and equipment used in combined cycle gas turbine.
- The steam is cool compared to combustion gases helping to cool the turbine interior.
- The system reaches full output more quickly than combined-cycle unit (30 minutes versus 120 minutes).

Additional advantages are that the amounts of power and thermal energy produced by the turbine can be adjusted to meet current power and thermal energy (steam) loads. If steam loads are reduced, the steam can then be used for power generation, increasing output and efficiency (Ganapathy 1994). Drawbacks include the additional complexity of the turbine's design.

The economics of a CHP system depend strongly on the local situation, including power demand, heat demand, power purchasing and selling prices, natural gas prices, as well as interconnection standards and charges, and utility charges for backup power. In some states, programs may offer support for installation of CHP systems (see also Appendix D).

Tri-generation. Many new CHP systems offer the option of tri-generation, which provides cooling in addition to electricity and heat. Cooling can be provided using either absorption or adsorption technologies, which both operate using recovered heat from the co-generation process. Because of the significant need for electricity, steam and refrigeration, the dairy industry may be in a prime position to take advantage of tri-generation.

Absorption cooling systems take advantage of the fact that ammonia is extremely soluble in cold water and much less so in hot water. Thus, if a water-ammonia solution is heated, it expels its ammonia. In the first stage of the absorption process, a water-ammonia solution is exposed to waste heat from the co-generation process, whereby ammonia gas is expelled. After dissipating the heat, the ammonia gas—still under high pressure—liquefies. The liquid ammonia flows into a section of the absorption unit where it comes into contact with hydrogen gas. The hydrogen gas absorbs the ammonia gas with a cooling effect. The hydrogen-ammonia mixture then meets a surface of cold water, which absorbs the ammonia again, closing the cycle.

Case study: Trigeneration

One food company that has successfully implemented absorption technology is the Ghirardelli Chocolate Company, a California based manufacturer of chocolate products. Ghirardelli's manufacturing facility in San Leandro, California, uses an on-site electricity generating system, which is powered by four 350 kW natural gas-fired reciprocating engines. In 2003, the company installed a single-stage 145 ton absorption chiller that runs entirely on heat from the engines' exhaust and jacket water. According to the company, the combined area of the buildings being cooled by the absorption chiller is approximately 35,000 square feet (Energy Solutions Center (ESC) 2005).

In contrast to absorption cooling, adsorption cooling utilizes the capacity of certain substances to adsorb water on their surface, from where it can be separated again with the application of heat. Adsorption units use hot water from the co-generation unit. These systems do not use ammonia

Case study: Backpressure turbines

Morning Star Packing Company, a manufacturer of tomato paste and other canned tomato products located in Williams, California, uses backpressure turbines to generate 100% of facility electricity needs (approximately 4.5 million kWh per year). In the mid- to late-1990s, the company installed three 1 MW backpressure turbines at a cost of around $847,000, including capital costs and installation expenses. Reported electricity cost savings have totaled nearly $500,000 per year. The company projected that over the 20-year lifetime of the backpressure turbines, they expect to save almost $9 million in total energy bills and realize a compound annual rate of return of more than 60% (Turbo Steam 2002).

or corrosive salts, but use silica gel (which also helps to reduce maintenance costs). Adsorption units were originally developed in Japan and are now also marketed in the United States.

The thermal performance of absorption and adsorption systems is similar, with a coefficient of performance between 0.68 and 0.75. The capital costs of both systems are also comparable. However, the reliability of an adsorption unit is expected to be superior and its maintenance costs are expected to be lower (Galitsky et al. 2005).

Backpressure turbines. At many facilities, steam is produced at a higher pressure than is demanded by process requirements. Often, steam pressure is reduced for process use by passing steam through pressure reducing valves, essentially wasting thermal energy. A backpressure steam turbine can perform the needed pressure reduction while converting this otherwise wasted thermal energy to electricity for use throughout the facility. According to the U.S. DOE, backpressure turbines can be considered wherever a pressure reducing valve has constant steam flow of at least 3,000 pounds per hour and when the steam pressure drop is at least 100 psi (U.S. DOE 2001c).

Photovoltaic panels. Photovoltaic panels convert sunlight directly into electricity and can provide a reliable and renewable source of electricity to facilities with ample sunlight. Photovoltaic panels, which are typically mounted on the roof of a facility, convert electricity to DC current, which is subsequently sent through an inverter and transformer and converted into AC power. The AC power can be fed directly into a facility's power supply. While the capital and installation costs of photovoltaic systems are currently somewhat high (typically ranging from \$6 to \$8 per installed DC watt), manufacturers can often receive substantial rebates and tax credits from state and federal agencies that can help make photovoltaic investments more economically attractive. Inverters typically last 10 to 20 years, while photovoltaic panels can typically generate power for 25 to 40 years (FIRE 2005c).

Solar thermal technologies. Solar thermal technologies also involve installing solar panels to harness the sun's energy. Instead of generating electricity, though, the panels absorb (and sometimes concentrate) the sun's heat, which is transferred to a heat transfer medium (e.g., water) running through piping in the panels. For water preheating, solar thermal panels reduce the heating load required to heat process or HVAC hot water. Water preheating can be a viable option in many parts of the country. For steam generation, however, a

Case study: Photovoltaic panels

Kettle Foods, a producer of all natural snacks based in Salem, Oregon, installed a 114 kW photovoltaic power system on the roof of its processing plant and headquarters in 2003. Reportedly, the system saves the company \$8,400 in energy costs each year, while also avoiding around 2,500 tons of CO_2 emissions. The initial capital and installation costs totaled \$675,000, but the company received over \$400,000 in clean energy incentives, Oregon energy tax credits, and U.S. federal energy tax credits, which helped to make the project more economically viable (Food Processing Industry Resource Efficiency (FIRE) Project 2005c). Over the 40-year life of the system, the company estimated a 7% average rate of return and a net present value of \$55,000. However, the project has also helped reinforce Kettle Foods' image as an environmental higher solar intensity and more expensive concentrating panels are required. Thus, this option is more geographically constrained with respect to its technical and economic viabilities (e.g., to the western and southwestern United States).

Case study: Solar thermal technologies

Oakhurst Dairy of Portland, Maine, installed a solar thermal preheating system, a project with a payback period of 8 years. However, the company claims that significant benefits also include an increase in employee morale from pride in the project, as well as positive public relations and marketing (D-CREE 2009).

Frito-Lay has installed a solar thermal concentrating system at its Modesto, California, plant to generate steam to heat the oil for producing Sun Chips. At full capacity, the solar panels in Modesto can produce enough steam to meet the energy demands of its Sun Chips manufacturing line (nearly15 million Btu per year). While Frito-Lay states that the costs of the system were “significant,” the company believes the sustainability benefits are worth the cost (Salerno 2008).

6 Energy Efficiency Opportunities for Bakeries

Energy efficiency measures described in this section are applicable to the practices, processes, and technologies used by commercial bakeries in the U.S. In addition to yielding substantial energy and energy cost savings, these divers measures can also result in increased plant throughput and in certain cases even improving product consistency and quality. Due to product production and current energy efficiency state, not all of the listed measures will be applicable to every bakery but should provide a starting point to assess potential improvements.

Technologies and operational practices detailed in this section have been identified from a number of sources including case studies, plant tours, energy audit records, trade publications, and academic literature. When available, energy and energy cost savings, payback periods, and other metrics are presented. These values are representative only as energy, material, and labor savings will vary from plant to plant, as they are dependent on plant capacity, configuration, location and operating conditions.

6.1.1 Ingredient Handling

Baking ingredients primarily come two forms, dry and wet. Major dry ingredients include flour and sugar to which minor ingredients are added. The amount of energy used to store and handle ingredients depends upon the type, quantity, and storage practices. Direct and indirect energy savings can be realized by improved handling practices of ingredients. Major wet ingredients are typically dairy products and water. Prior to use dry ingredients maybe stored at the plant in conditioned environments that are cool and dry. Major ingredients can be stored in silos outdoors but are typically must be brought to a desired temperature before being processed. Dairy products are commonly stored in silos and regulated by strict food and safety rules.

Simple changes in the way ingredients are handled and stored can lead to energy savings. By covering open storage bins the chance of foreign matter contaminating ingredients is reduced. In addition to preventing spoilage this action can help maintain ingredient temperatures, reducing the potential need to cool ingredients before processing. Taken at other bakeries, this action typically has a payback period of less than three months (IAC 2011).

Ingredients can be manually or automatically measured and distributed. Controls and automation have become increasingly important as bakers seek to mitigate possible operator error and contamination issues. Ingredient control systems can measure and confirm that the correct amount of ingredients have been sent to the mixer. Automatic controllers can be used to send ingredients to the mixer based upon preset recipes. Control systems can be integrated with temperature and other quality sensors and inform bakers before ingredients spoil or if they need to be conditioned before processing (Whitaker 2012b).

Ingredient distribution conveyors maybe left on to run continuously even during stoppages, changeovers, and weekends. A person should be tasked with ensuring distribution conveyors are turned off during these times. Alternatively, a central controller can be programed to turn conveyors on and off as needed, further reducing the potential that conveyor motors are left to run when they are not needed (CoA 2000a). Installation of automatic distribution equipment typically has a payback period less than six months (IAC 2011).

Dough temperature is critical to consistently producing quality products. Controlling the temperature of ingredients before they enter a mixer may result in a small increase in upstream production energy consumption but can offset energy used to cool dough as it is mixed. When flour is chilled before mixing, cooling time of the prepared dough is reduced by about five minutes. Chilled flour systems are most commonly used in production lines that produce yeast-raised baked dough when yeast activity needs to be retarded. Manufacturers that produce dough that is sold chilled or frozen can use flour-chilling systems to reduce energy requirements of less efficient freezer systems (Whitaker 2012d). In some cases ingredients can be chilled by the addition of other ingredients such as water or nitrogen.

6.1.2 Ingredient Mixing

The mixing process offers energy saving opportunities. Besides the motor itself, the main requirement for energy in the mixing process is cooling to extract heat from the product as it is processed.

Different dough and batters are best processed at different temperatures. For products that contain yeast, the desired level of yeast activity typically determines the ideal temperature. By producing dough and batter at ideal temperatures processing equipment such as dividers, shapers, pumps, and extruders will appear in an efficient manner (Whitaker 2012i).

If producing dough, bakeries should consider equipment or operating equipment in a way that requires less cooling. The friction between the mixer and ingredients develops a large amount of heat. If dough is properly kneaded and not simply mixed, less heat will be generated, resulting in lower cooling demands. With careful operation some dough can be kneaded so that a mixing bowl jacket is not needed and cool water, not ice, is only used in the recipe. Mixer control packages that monitor dough development rather than simply measure mixing time can be used to reduce the potential for over mixing.

Variable speed drives. Mixers with variable frequency drives (VFDs) offer high levels of control and flexibility to bakers. VFD mixers can be used to operate at different speeds, accelerations, and durations to enhance the mixing and development of dough. VFD mixers can operate at slower speeds, reducing the amount of energy transferred to the dough and decreasing the energy required to cool the dough. VFD mixers experience less wear and tear as motor and drive component speed can be ramped up and down instead of being shocked to life as with a two-speed motor.

Continuous mixers. Continuous mixing systems are able to limit dough exit temperature in three ways. As continuous mixers require less energy to produce dough, the amount of energy that enters the dough production process is lower, providing less potential energy to heat the dough. In a continuous mixer, ingredients are added at the same time instead of individually, removing the need to pre-blend the ingredients before production. By removing the pre-blending step mixer energy can be reduced by as much as 20%. While a traditional mixer will contain the dough it is producing in a large mass, continuous mixers increase the surface area of the dough, and subsequently the effective cooling surface. This increases the effectiveness of cooling equipment, as more dough is able to come into contact with cool surfaces. Lastly, because the dough is stretched out, it is not as thick as it would be in a traditional mixer. This allows for quicker heat dissipation from the dough central mass to the cooling surfaces (Whitaker 2012i).

Controllers and instrumentation allow bakers to monitor and record dough temperature, coolant temperature, and energy consumed by the mixer. This information can be used to optimize the mixing process to consistently produce a high quality product in an energy efficient manner (Thilmany 2009b, Whitaker 2011b).

Batter. Enhanced mixing control is also beneficial when producing batters. When exiting the mixer, batters can have too much or too little air incorporated, changing the viscosity of the liquid. This can increase energy demand, as pumps may have to work harder to move product from the mixer to later stages of production. Batter quality can be controlled to ensure aeration consistency. The same controllers can be used to make sure batter is properly deposited into pans so that product is not lost and wasted (Atchley 2012a).

6.1.3 Proofing

Proofing of dough requires a conditioned space that provides a desired ambient temperature and humidity, typically around 40°C and 70 to 80% humidity (EMIAA 1998). Depending upon the size and needs of the bakery, proofing can be accomplished in small boxes or in large rooms. Creating an energy efficient proofing system includes selecting and maintaining the correct ambient conditioning equipment and ensuring that conditioned air does not escape the proofer. Automation inside the proofer to physically knock down dough as it rises limits the number of times a person must enter the proofer, decreasing the release of conditioned air.

Proofer room or boxes are conditioned to a temperature and humidity specific to the needs of the dough being developed. Ideally, the temperature should be set not as a singular point but as a tolerable range. The range should be targeted enough to keep the dough healthy and to produce a consistent final product but as large as possible to decrease the energy used to condition the room (CoE 2000a). Additionally, proofer temperature and humidity sensors and controls should be periodically checked and recalibrated as needed. Recalibration of sensors has a 1 to 3 year payback period. Proofer insulation should be checked and upgraded to ensure conditioned room air is not escaping. Consider replacing door seals to ensure a tight envelope is created.

Case study: Innovative proofing

The Bakers Delight showcase bakery outside of Sydney, Australia, was designed to demonstrate best practices in energy efficient bakery design. A prototype proofing system here uses an innovative modular approach. The system includes two proofing cabinets, one with two sealed doors, each holding one rack, and the other with three sealed doors, each holding one rack. Both cabinets have separate heating and humidifying systems, allowing bakers to utilize only the proofing capacity they need. Furthermore, heat losses are minimized since bakers open each door separately to remove each rack. (DITR 2003).

Heating and humidifying the proofer room/boxes can be accomplished through a number of alternative energy saving methods. Proofers are typically heated and humidity by a boiler that is also used for building heat, hot water production, and other heating and steam needs. Alternative sources of heat and steam can be found throughout the bakery but must be assessed by each bakery as various factors such as the location of equipment and quality of heat can limit the economic and energy savings potential of implementation. Potential options are listed for consideration (CoA 2000a):

- Lower steam pressure - payback period 6 months
- Direct gas-fired with water sprayers - payback period 4 years
- Oven heat recovery - payback period 3 to 5 years

6.1.4 Process Heating (Oven or Dryer)

Ovens and dryers can consume more than 10% of a bakeries total energy and 26 to 75% of process specific energy, typically in an inefficient manner. Dryers often consume two to three times as much energy as thermodynamically required to remove a pound of water from product. Ovens are typically even less energy efficient, consuming five or more times as much energy as thermodynamically required to heat product. The vast majority of this extra energy is lost as heat to the outdoor environment through the oven or dryer stack. The type of heating element selected for use in an oven or dryer greatly affects the thermal efficiency of the system. Gas burners are 85 to 95% efficient while steam heat systems are 70 to 80% efficient. Due to losses at the power plant and transmission lines, delivered electricity is only about 30% efficient. Advanced baking technologies such as radio frequency assisted ovens provide an energy efficient way for goods to be baked that requires low final water content (Whitaker 2011c).

Case study: Efficient oven by design

The Bakers Delight showcase bakery outside of Sydney, Australia, was designed to demonstrate best practices in energy efficient bakery design. An electric oven was designed for this bakery that delivered large energy savings through the following features (DITR 2003):

- insulated solid doors with no glass windows;
- improved insulation in walls, between decks, and in the main drive shaft;
- energy efficient light that turns off when the door is opened;
- seals attached to all four sides of the doors; and
- individual programmable temperature and time controls for each deck.

6.1.5 Oven selection and installation

As a key piece of energy consuming equipment in a bakery the oven offers many energy savings opportunities. Ovens typically have life spans greater than ten years, making procurement of a unit that is energy efficiency important. Modern ovens are significantly more energy efficient that they were even five years ago (McMullen 2010a). Many factors should be considered when selecting an oven. Ovens come in many forms including rack and deck styles that bake product in batches as well as tunnel ovens that can be used to continuously convey product (Thompson 2007).

Heating sources too come in many forms such as radiant, convective, or impingement (Rigik 2009). Additionally, there are alternative baking and drying technologies such infrared units to consider. Carful, maintenance, control, and operation of an oven can greatly improve the overall energy efficiency of a bakery. While large, direct energy efficiency savings can be found in improving the efficiencies of technologies such as motors and equipment insulation, indirect benefits can be realized by improving oven and dryer design, production throughput, decreasing downtime, and optimizing production processes.

Oven placement. When installed, ovens should be placed in a well ventilated space away from other processes that require a cooler environment such as cooling racks, ingredient storage areas, and mixers. Oven isolation can be accomplished by means of simple Teflon curtains and proper ventilation. Insuring the oven is properly insulated will increase the energy efficiency of the oven. In addition to insulating the oven itself, insulation of other bare equipment such as exhaust stacks should be considered. Insulation of the oven typically has a payback period of about 1.5 years while other equipment insulation projects have been shown to have 0.5 to 1 year payback periods (IAC 2011).

One common flaw in oven design allows large quantities of air to infiltrate and cause drafting. Warm conditions inside an oven result in a natural convection of air, drawing conditioned air from the bakery into the oven and out the stack. This results in lot conditioned air as well as more air that is required to be heated by the oven (Malovany 2010). Ventilation doors that span multiple rooms need to be controlled to reduce drafts that can pass through the oven and affect temperature levels/gas usage.

6.1.6 Oven flexibility

When selecting an oven to install or looking to upgrade an existing oven, consider a system that is flexible in what products it can produce. Increasing the amount of one product made or diversifying the product line to include various baked goods can increase the overall energy intensity of a bakery (BTU/pound product produced). By producing more than one product bakeries can increase production and minimize downtime. Even when an oven is purchased to produce only one type of product the oven should be designed to produce any foreseeable variations of that particular product. These design considerations typically focus on advanced controls and building an appropriate mix of convection and direct-fired modules into the oven.

Flexible production. Ovens that are designed with operational flexibility in mind can accommodate expanding or shifting production better than ovens built for one type of product. Points to consider when looking to purchase an oven that will provide the flexibility necessary for multiple products include a balance of radiant and convection heat in different sections and the choice of an open mesh, closed mesh, or solid steel belt. Closed mesh belts typically offer greater flexibility as they can be used to bake cookie type products that need a more solid base to sit on and the ability for air to flow up through the belt to assist in drying cracker type products (Whitaker 2012e).

Multilevel oven. Product flexibility can also be accomplished by using a multilevel oven. Multilevel ovens offer the potential to bake multiple products at once, increasing the diversity of a bakery as well as throughput. These ovens can be controlled so that different levels within the over are set to different temperatures, air flows, and humidity levels. As production demands change the number of levels set to bake a single product can be changed, adapting to the needs of the bakery. As ovens represent a potentially five or ten year investment for a bakery, maximizing product flexibility will help bakeries easily transition to new products in an efficient manner (Whitaker 2012f).

6.1.7 Operating conditions

To maximize oven or dryer efficiency, equipment should be operated in a way that considers energy consumption. Ovens should be operated for as short of a period as possible. Scheduling baking to ensure the oven is filled when in use can reduce standing losses. Procedures should be implemented that minimize the amount of time a hot dryer or oven is empty.

The lowest exhaust air temperature and flow rate should be used to produce a product with optimal settings determined for each product the plant produces. Product should be put into the baking device at a maximum capacity, leaving little or no extra space left open. For ovens and dryers that use conveyors, product should be distributed across the full width of the belt and as uniformly as possible.

Product entering the oven or dryer should contain as little water as possible. Increased monitoring and recording of production variables will help bakers understand how much energy is required to produce their product.

Heat-up time. The oven warm up period should be kept as short as possible. To become more energy efficient the minimum oven heat-up time should be determined. One bakery reduced heat-up time by 20 to 25 minutes for cabinet ovens and by 40 to 50 minutes for tunnel ovens. The process of determining the minimum oven heat-up time must be conducted in a way that does not impact product quality or the required baking schedule. Two methods for establishing a minimum heat-up time are (CoA 2001):

1. Record how long after start-up the oven temperature sensors indicate a desired baking temperature. This value is the minimum heat-up time and is the absolute minimum time needed before product enters the oven. To ensure all products are fully baked an oven start-up time should be established that is greater than the oven heat-up time.
2. Starting with the current operating parameters, gradually delay the oven start-up time (e.g. 15 minutes at a time), over several days, until you find the shortest time needed to start the oven while ensuring all products are baked. Decreasing the start-up time by small amounts will ensure you achieve energy efficiencies without adversely affecting your product quality. This method will not indicate the absolute minimum heat-up value.

Temperature profiling. Oven temperature profiling can assist in oven tuning and baked goods optimization. Temperature profilers are fitted with multiple thermocouple temperature sensors mounted along the width of the belt on a pan. The sensors travel through the oven capturing a picture of the oven's thermal profile. More advanced profiler devices will also read and record oven airflow and moisture levels. Oven optimization issues such as left right differences and cold and hot spots are revealed, indicating areas in need of maintenance (Whitaker 2012h).

6.1.8 Waste heat use

One of the most important design considerations when considering an oven or dryer is the use of waste heat. Waste heat can be used in a number of ways, some directly at the oven or dryer and others around the bakery. The use of oven waste heat is most readily available to bakeries that produce products that require proofing. When products do not call for proofing, such as cookie, cracker, or biscuit production, the use of waste heat is typically limited to the production of hot water (Malovany 2011).

Before hot air in the oven or dryer is vented it should be re-circulated if possible. Air recirculation reuses a portion of the hot exhaust and transfers it to a lower temperature section of the oven. This action has to be balanced by humidity needs of the product being produced.

An energy advantage can be gained by using a heat exchanger to pre-heat the air required by the burner for combustion. In this way fuel normally used to heat the combustion air to the stack temperature is saved. The warmer air raises the temperature of the flame in the radiant section and increases the heat transfer. The result is a lower temperature in the exhausting stack gases and lower fuel consumption. An air-to-air heat exchanger can be installed in the exhaust stack so that the stack gases are cooled slightly before they are passed to the atmosphere, and the incoming combustion air is pre-heated before it is passed to the combustion system. This action may cost on the order of $8000 with typical payback two to four years (CoA 2000a).

Case studies: Waste heat recovery

In response to rising energy prices and taking advantage of new facility construction, Weston Bakeries in Winnepeg, Canada, installed a heat recovery system on its rolls and bread ovens. The system saves between 86,000 and 95,000 cubic meters of natural gas a year and delivers a minimum savings of $27,000 in avoided natural gas costs per year (NRCAN 2010).

Similarly, a Buttercup Bakeries in Melbourne, Australia, installed a heat recovery system on its bread baking oven to provide heat to its proofing oven. The estimated payback period was 3.5 years. Additional benefits included less boiler water treatment and less maintenance on the boilers (EMIAA 1998).

6.1.9 Oven Burners

Efficient oven burners are a critical component of bakery energy efficiency. Burners should be checked based upon a predictive maintenance plan. Stack emissions should be analyzed to ensure burners are not out of specification. Proper burner maintenance will help bakeries that operate with air quality permit to ensure their stack emissions are within permitted levels and avoid fines. Damaged or obsolete burners should be replaced with more efficient ones. This action typically has a payback period of 1.5 years (IAC 2011).

Burner optimization can be determined by analyzing the combustion stack gasses. When first installed and commissioned, burners can be adjusted for efficient operation, an action with a five to ten month payback period (IAC 2011). As a part of commissioning, a stack sample should be taken for reference. Periodic stack sampling can be performed and differences in stack exhaust levels will indicate problems with one or more of the burners. An oxygen or combustion analyzer along with stack temperature measurement can be used to determine a host of potential energy inefficiencies. If the combustion efficiency is lower than when the oven was commissioned appropriate strategies should be developed to improve this efficiency (CoA 2000a). Typically the combustion air/fuel ratio will need to be adjusted or in some instances a burner will be damaged and needs to be repaired or replaced. Damaged burner repair commonly has a payback period of 1.5 years (IAC 2011).

Three possible outcomes from stack gas analysis are:

- Excess air: Adjust and maintain the air/fuel ratio so that it is optimized for the operating load condition of the oven. An oxygen trim control may be appropriate to control systems where combustion inefficiencies cannot be managed by air/fuel ratio adjustments. Oxygen trim controllers cost between $6,000 and $10,000 to install, but will reduce time required to assess efficiency and maintain oven efficiency in the future.
- High stack temperatures: As discussed in the previous section, energy wasted as stack heat can be recovered and either used in other parts of the bakery or used to preheat combustion air for the oven. This action reduces flue temperature and improves combustion efficiency. This action may cost in the order of $8000 with typical payback two to four years.
- Incomplete combustion: A lack of adequate combustion air will lead to incomplete combustion. This will result in unburned or partially burned fuel being released from the oven, wasting fuel and potentially violating air permits. Possible fixes include burner control adjustment and burner maintenance. (CoA 2000a)

6.1.10 Maintenance

Ovens and dryers should be well maintained. Part of regular oven and dryer maintenance should include looking for air leaks (IAC 2011). Air leaking into the dryer or oven results in increased energy consumption, as this additional air also must be heated to ensure the product is baked. Air leakage out of the oven is a source of wasted energy, heating the surrounding air and not the product. Depending upon the bakery, leaked hot air must be cooled to the building temperature by an HVAC system. Repairing air leaks is cost effective and typically has a payback period of less than one year (IAC 2011).

Oven and dryer controllers should be tested and calibrated in order to achieve the efficiency gains that can be realized by their use. These devices should be checked based upon manufacturer specification or when production and energy data indicates a potential issue with the devices.

Creating a temperature profile of the oven will indicate temperature imbalances across the width of the oven. Temperature imbalances should be investigated and corrected. This might require adjustment or replacement of burner elements or repairs to insulation. An oven temperature profile will also indicate stages of the oven that are too hot or cool, potentially impacting product quality (CoA 2000a).

6.1.11 Controls

Control measures are able to save energy by interfacing with just the oven or by integrating oven control with the bakery system as a whole. Oven exhaust ducting can be actively controlled to minimize the energy required to ensure combustion exhaust is expelled safely from the bakery and that ambient air is not able to enter the bakery through the exhaust system. Exhaust control uses external pressure, wind, and temperature data to control variable speed motors. These types of systems can result in 5 to 20% energy savings. Exhaust control systems can be coupled with heat recovery devices to produce hot water (Exhausto). Additionally, self-adjusting dampers on air intakes will prevent migration of outside air into the oven during pre purge and gas exhausts. Removal of barometric dampers from forced draft ovens will also reduce the amount of conditioned bakery air being sucked out of the building through the oven while preventing cold air from being drawn in while the oven is not running.

Case study: Oven hood controls

The Bakers Delight showcase bakery outside of Sydney, Australia, was designed to demonstrate best practices in energy efficient bakery design. Among its many efficient technologies is an innovative oven hood design, which includes adjustable speed drives on its supply and exhaust fan motors. The control system allows the motors to run on low speed until an oven door is opened, at which point the motors are run at high speed. Additionally, back draft dampers were installed in the ceiling space to prevent infiltration when the fans are switched off. The oven hood design reportedly reduces energy use by nearly 75% compared to standard designs (DTIR 2003).

Control systems can be used to greatly expand the usefulness of an oven. A centralized controller can make adjustments to how the oven is being heated to accommodate different product types as well as minimize start up and shut down energy requirements (Whitaker 2011c). Centralized control allows bakeries to utilize a multiple zoned approach to baking that promotes product flexibility. Product can be tracked throughout the production process and oven settings can be adjusted based upon known product changes that will soon be ready for baking. Working with the controller, a direct spark ignition system can provide oven flexibility by changing burner firing as the type of product entering the oven changes. A direct spark ignition system controls each individual burner separately, allowing for individual burners to be turned on and off in various configuration depending up on the needs of the product entering the oven. By linking the system to a central controller these settings can be automatically changed based upon product type (Malovany 2010, Whitaker 2011c, 2012g).

In addition to directly controlling the oven, controllers can provide bakers real time information on screen regarding equipment issues, recipes, baking temperature, time, steam, convection, pan size, up and down stream production issues and other information. Managers can use this data to see real time production statistics and compare to historic trends. Recorded data can be used in many ways including to create custom reports, trending, or maintenance personnel troubleshooting.

Case study: Thermal oxidizer controls

A U.S. bread plant utilized adjustable speed drive controls on its thermal oxidizer blower. The control strategy was based on the blower's inlet pressure, which allowed the blowers to be ramped down when one or more of the plant's ovens were not in use. The measure is expected to reduce plant energy costs by $7,700 per year. At an investment cost of $633, the expected payback period was less than two months (Base 2012).

6.1.12 Radio frequency ovens

Bakeries that produce products with low water content, such as cookies and crackers, may want to investigate the use of a radio frequency oven. These ovens contain a section that exposes product to an electronic field that produces energy waves that pass through the air alternating at frequencies around 40,000,000Hz. As the waves alternate water molecules in the product are energized and spin. This motion creates friction, heating the product throughout the product where water is located. Because of this action, areas of the product that are already baked and do not contain high water concentrations are not heated. This system results in an easy to control baking process and increased throughput.

Because radio frequency ovens only heat the product itself, and not the air surrounding the product, there is less energy waste. Within the U.S., radio frequency ovens do not account for a large percentage of bakery ovens. The U.S. accounts for less than 7% of the world radio frequency oven market share. Studies have concluded that the benefits of radio frequency ovens are not widely understood in this country (ECOW 2000b).

Case study: Radio frequency drying

A Pepperidge Farm plant in Denver, Pennsylvania, employed a radio frequency dryer to increase the production throughput on its Goldfish cracker line. Normally, increasing the Goldfish oven throughput would raise the moisture in the final product to an unacceptable level. However, installing a radio frequency dryer after the oven to drive off this additional moisture allowed them to double production throughput without adding a new Goldfish line (Malovany 2006).

6.1.13 Cooling and Freezing

Cooling. The sole use of unforced ambient bakery air to cool products is typically unacceptably slow. Hence, the addition of energy consuming devices to speed up the cooling process is required. When considering cooling bakery products a balance between energy consumption and throughput must be made.

Using compressed air to cool products is needlessly costly and instead air blowers and fans should be considered. Eliminating unneeded compressed air has been shown to have a payback period of less than one year (IAC 2011). Controllable exhaust fans may improve air circulation and create a more even distribution of cooling air. The exact placement of exhaust fans needs to be careful considered if they are to be effective. (CoA 2000a)

Bakery products should be cooled away from heat sources such as ovens. To save plant floor space, spiral conveyor cooling racks can be installed. Spiral cooling racks can be enclosed with low cost materials to shield the cooling process from heat sources. These enclosures will also aid in keeping foreign debris away from the product (McMullen 2010b).

Automatic control of a cooling line can improve energy efficiency and product quality. A cooling line system control unit can control the entire cooling system, including line speed and exhaust fans. This type of system integration has been shown to reduce maintenance costs and facilitate a flexibility allowing for easy modification to the cooling system. Such a control unit may cost about $7,500 fully installed and result in a reduction in cooling time of about 25% (CoA 2000a).

Freezing. The choice of a freezer should be made with product needs and energy efficiency in mind. Typically bakeries that need to freeze their product will chose between a batch or continuous line freezer. The shift from continuous to batch production is typically not encouraged and can create unnecessary bottlenecks in a production line. Such bottlenecks are not energy efficient as extra labor is needed to ensure production continues and other equipment, such as an oven, may need to be left in an operational mode while waiting for the line to continue before product is produced. An automated continuous freezer can decrease labor and energy requirements.

Bakeries typically consider one of two continuous freezer technologies, spiral or linear tunnel freezers. The choice of technologies is primarily based upon product needs and available floor space. Spiral freezers are able to fit more belt length into a smaller footprint as compared to linear freezers and are well suited for products that need to be frozen in a controlled manner. Spiral freezers can be arranged so that products progressively enter colder zones, preserving product features. Linear freezer tunnels do not share the flexibility of spiral freezers but will typically freeze products quicker. Where a spiral freezer may require 45 minutes for a product to travel the length of its belt, a cryogenic tunnel freezer could have the same product frozen in just 15 minutes. The use of high velocity air in a freezing tunnel can alleviate some of the energy and operational costs associated with a cryogenic freezer (Atchley 2011b).

6.1.14 Cleaning

Food safety standards and good operating practices require a bakery be keep clean. Cleaning within a bakery can be performed in many ways and is dependent upon the equipment or area being cleaned, accessibility, and time allotted for cleaning (Thilmany 2009a).

Water use. Many bakeries make efforts to reduce the amount of water used while cleaning equipment and the surrounding spaces. Water can be both expensive and energy intensive if heated or cleaned before discharge. Eliminating or reducing cleaning water is encouraged. Areas that can be dry cleaned should be identified. In addition to reducing water consumption, dry cleaning can reduce microbiological issues. In cases where hot water is absolutely necessary for cleaning, roof mounted solar water heaters or waste heat recovery systems can be used as alternatives to a boiler or traditional hot water heater.

Compressed air. Compressed air is often used in lieu of water to clean down slicers, bagging machines, conveyors and floors. This practice is highly energy intensive and should be avoided if possible. Additionally, cleaning with compressed air does not typically remove debris from the plant but blow them into the air to settle in another location. Compressed air systems typically leak and manual valves are left open. Care should be taken to compress air to as low of a pressure as possible, reducing valves, and standard air guns, along with appropriate training to instruct users to be conscious of compressed air use (CoA 2000a, CoA 2000b).

6.1.15 Clean in place

Dairy products. Bakeries that have onsite dairy storage systems are probably required to follow additional sanitary regulations. Meeting these regulations is most commonly achieved by using a Clean in Place (CIP) system that allows the baker to clean and sanitize the storage equipment without having to disassemble and reassemble the equipment. CIP systems utilize a series of steps centered on rinsing the equipment with a series of chemicals and hot water. Due to the multiple steps and washes associated with CIP, it is a significant source of water and energy use (Chisti 1999, Ecolab 2011). Energy and water used by a CIP system can be reduced in a number of ways:

- **Using reuse or recovery distribution systems**: Overall, there are a few types of CIP distribution systems that are widely used. Single use systems, which dispose of the rinse water and cleaning solution after one use, are the most versatile. However, these systems use copious 101quantities of water and energy in the cleaning process. More efficient systems are reuse systems and solution recovery systems. These systems can reclaim the alkaline detergent solution and reuse it for future cleaning. In addition, the relatively clean final rinse water can be captured and used for the next CIP cycle's initial rinse (Ecolab2011).
- **Single phase cleaning:** The use of a single cleaning solution that removes both organics and mineral deposits can eliminate the need for a two-step (i.e. separate alkaline wash and acid wash) cleaning process. This technique saves water associated with the interim rinse step and the second wash. This measure estimates a 25% water reduction and 10% energy use reduction compared to a typical five-step process (Ecolab 2011).
- **Over-ride procedure:** This technique is generally used for equipment that requires a fast turnaround. Instead of separate acid wash and alkaline wash steps, the first step (acid step) is kept circulating while alkaline detergent is added to the required concentration. Although more detergent is used with this technique, since some must be added to neutralize the acid, approximately a 10% water reduction is possible (Ecolab 2011).
- **Pulse rinse on tanks**: Often a constant stream of water is used in rinse steps. However, a pulsed rinse, where the water is stopped periodically throughout the step, can be more effective at rinsing while reducing water usage by approximately 10% (Ecolab 2011).

Ovens. As with the rest of the bakery, oven sanitation is important. Left over product can accumulate in the bottom, get gummed into belt mesh, and block burners. Ovens should be cleaned on a regular schedule to ensure product quality and consistency (Thilmany 2009a, Zietlow 2012). Preventative cleaning devices can be installed on ovens. One such device blows off product debris form the mesh chain before the mesh is oiled, reducing the rate of buildup (Thompson 2007). To aid in oven cleaning oven access panels should be placed in logical locations and be large enough to facilitate manual cleaning. Just as with dairy storage systems, automated CIP systems have been developed for ovens. A CIP system uses cycles of heated water and cleaning products to wash out ovens. These CIP systems can be operated manually or integrated with oven controllers for automated operation (Whitaker 2011c).

6.1.16 Slicing and Packaging

Increasing plant throughput and decreasing stoppages can indirectly reduce energy consumption. Slicing and packaging operations tend to be a bottleneck in production. These operations need to run smoothly and consistently to reduce the potential for plant shutdown and to increase production rates. Even modifying existing slicing and bagging systems with low air nozzles can save energy and has a short two to four month payback period (IAC 2011).

New slicing and bagging technologies are able to operate at production speeds by keeping designs simple and motions short. Auto diagnostics on modern baggers can detect jams in the system, such as fallen product, and automatically attempt to remove the problem with compressed air.

Parallel operation. Bagging devices can communicate with the operator and plant control system to inform both when there are potential issues and to adjust production speed accordingly. With this central control capability, operating multiple slicing and bagging machines in parallel at 70% to 80% of full speed capacity is recommended. In this way if a single machine is taken out of operation for any reason the remaining machines can increase speed to 100% so that the plant as a whole does not experience a slowdown.

Twin-headed slicers. Another way to reduce slicer downtime is to buy modern slicers that have twin-slicing heads. When one slicing head needs to be removed, repaired, and replaced it can be removed and its twin head installed in less than a minute, causing only a minor disruption in production without a plant shutdown. Traditional one head slicers do not allow for operation while the head is removed for repair (Atchley 2012b, Malovany 2012).

6.1.17 Frozen Storage

Freezer control systems can be used to ensure products are correctly cataloged, stored, and removed before expiration. Double handling of product increases energy consumption through increased forklift use, opening of freezer doors, and potential for loosing track of and damaging product. Controllers that are programed to follow first-in first-out principles will help reduce unnecessary storage freezer entry. Controls can also assist in maximizing freezer utilization. During a series of audits freezers were observed to be up to 95% unoccupied, resulting in a large volume of air being conditioned for not practical purpose. For bakeries that do not have cross contamination potential, freezer-scheduling strategies should be developed to maximize space utilization to reduce energy consumption by empty freezers (CoA 2000a).

Robotic movement. Robotic palletizers and moving equipment can be used to automatically stack, move, and track pallet progress from packaging through the warehouse/freezer and to shipping. Such systems are especially useful when conforming to the more strict Food Safety Modernization Act that calls for greater control over the movement of food products. Robotic movers reduces the requirement for humans to enter the freezer, reducing thermal stress on employees as well as energy costs by keeping doors closed more often and not needing forklifts to enter the cold space. The automatic system only requires small, fast action doors to open and closes when quickly transferring product into and out of the freezer. With the reduced need for humans to enter the freezer lights can be shut off and only turned on when access is needed. Fast starting LED lights can make this type of operation possible. Occupancy sensors and thermal cameras should be considered to make sure humans are not accidentally trapped in the freezer (Whitaker 2012a).

6.1.18 Miscellaneous

Other bakery specific energy savings opportunities should be considered. These opportunities are typically not associated with a single stage of the baking process and costs, payback periods, and energy savings levels vary greatly as they would be applied uniquely to each plant.

Product movement. Moving product around the plant can be a time, energy, and labor consuming process. Automated conveyor belts, tracks, and stackers can be installed to move product. These systems typically have longer payback periods but can be instrumental in increasing plant throughput. Moving systems reduces the need for forklifts and other heavy lifters that may be oversized for the job they are performing.

Conveyors. When considering the installation of conveyors it is important to remember that conveyors may run continuously, even during times of stoppage, changeover, and on weekend. This issue can be resolved by delegating responsibility for switching off conveyors to a single point of control. Additionally, system automation can be integrated to only operate conveyors when product needs to be moved (CoA 2000a).

Pan stacking. Automated equipment that can take move, stack, and store pans are of potentially high value to a bakery for a number of reasons. Hot metal pans can cause burns or lifting and moving pans repeatedly that risks repetitive motion injuries. As bakeries increase line speeds with larger pans, they risk greater chances for workers to sustain back injuries. By automating pan-handling safety risks to employees are minimized and throughput can be increased.

Additionally, a bakery may require different types of pans to accommodate the range of different products produced. Manual pan changes take longer to accomplish than an automated system, increasing production stoppages and energy consumed to keep waiting ovens warm and dough at an appropriate temperature. Most automated pan systems have a return on investment of three years or less (Whitaker 2012c).

Refuse removal. Refuse removal operations do not typically demand a large amount of energy but can be a costly part of a bakeries operation. Trash and recyclables compactors reduce the amount of space required to store refuse before removal. As compacted refuse takes up less room fewer truck are required to remove the waste from the plant, potentially a lowering costs. Space saved from compacting refuse can be used for other operations or closed off and the lighting and conditioning needs removed. Payback of a refuse compactor can be as short as six months to one year (IAC 2011).

6.1.19 Emerging Technologies

The previous parts of this section discussed a wide range of energy efficiency measures and practices that are based on proven, commercially available technologies and operations. In addition to these opportunities, there are also a number of emerging technologies that hold promise for improving energy efficiency in the baking industry. (An emerging technology is defined as a technology that was recently developed or commercialized with little or no market penetration in the baking industry at the time of this writing.) New and improved baking technologies are being developed and evaluated continuously, many of which can provide increased energy savings, product consistency and quality, and improved productivity. Three emerging technologies are briefly discussed.

Infrared ovens. Infrared ovens use electric coils or ceramic plates heated by flames to generate and transmit infrared energy to the surface of a product without heating the surrounding air, akin to being heated by direct sunlight. This results in a reduced baking time, lower oven emissions, and a smaller oven footprint. This type of heating is reported to be 50 to 80% more efficient than convection ovens as a large volume of air does not need to be heated (ECOW 2000a, European Commission 2009).

Reflective coatings. Advanced coatings can be applied to pans along with interior walls and burners of installed or new ovens. These materials are sometimes referred to as nano-emissive coatings, one of which is a NASA-licensed technology, contain high-emissivity ceramic materials that increase oven energy efficiency by absorbing heat and radiating it back to the product in the form of infrared energy waves. This allows a greater portion of the original energy contained in the burned fuel to be applied to the product, reducing the amount of fuel required by up to 20%. In addition to energy cost savings, reduced fuel consumption results in fewer emissions, potentially negating the need for costly post combustion pollution control equipment. The coatings are able to extend oven life by decreasing the amount of heat that oven walls and burners are exposed to (Whitaker 2011a).

Phase change materials for freezing. Advanced phase-change materials (PCMs) are used being used to control thermal loads in commercial buildings. While they can come in many forms, PCMs are typically salt mixture filled into plastic containers and submerged in a tank of water, glycol, or other liquid that readily transfers heat. This heat transfer fluid is connected to a thermal source such as a boiler or chiller via a heat exchanger. The PCMs absorb or release thermal energy based on their temperatures and the temperature of the fluid. Commercial buildings use this technology to gain an energy cost savings by running their air refrigeration systems at night when electricity rates are lower, store the energy, and then use the energy to cool the building during the day when electric rates are higher.

In a similar manner bakeries can operate their chillers at night cooling the PCM. This load can be used later during nonpeak times throughout the production process where cooling is needed. In addition to potentially gaining and energy cost savings, this eases the burden on a plant's chiller system, effectively increasing the total chilling capacity of the plant. In some cases, facilities with PCM equipment are able to use their chillers to handle 75% of the cooling demand with PCMs supplying the remainder of the chilling demand (Atchley 2011a).

7 Basic Water Efficiency Measures

This section provides a brief overview of basic, proven water efficiency measures applicable to typical baking plants. In addition to reducing facility utility bills for water purchases, improved water efficiency can also lead to reduced energy consumption for water pumping and heating, reduced wastewater discharge volumes, and reduced wastewater treatment costs. In addition, several of these measures have additional benefits, such as waste heat recovery and reduced amount of cleaning chemicals required. Finally, water efficiency also reduces loads on local fresh water and wastewater treatment plants, which leads to indirect energy savings in the industrial water supply chain.

Strategic water management program. Similar to a strategic energy management program, a strategic, organization-wide water management program can be one of the most successful and cost-effective ways to bring about lasting water efficiency improvements. Strategic water management programs help to ensure that water efficiency improvements do not just happen on a one-time basis, but rather are continuously identified and implemented in an ongoing process of continuous improvement.

Establishing and maintaining a successful industrial water management program generally involves the following key steps (NCDENR 1998) (CDWR 1994, NHDES 2001):

1. **Establish commitment and goals**. Goals for water savings should be qualitative and included in statements of commitment and company environmental policies. A commitment of staff, budget, and resources should be established at the outset of the water management program to ensure success.
2. **Line up support and resources.** Internal and external staff and resources should be identified and secured, including a water program manager, with buy in from senior level management. Many of the recommendations for establishing an Energy Team are applicable at this stage.
3. **Conduct a water audit.** A facility water audit should be performed to identify and document all end uses of water, daily or hourly water consumption rates for all end uses, and water efficiency practices already in place.
4. **Identify water management opportunities**. Based on the results of the audit, opportunities for the elimination, reduction, and reuse of water applicable to each end use should be identified.
5. **Prepare an action plan and implementation schedule**. Cost-benefit analyses on all identified opportunities can be performed to determine the most practical ways for meeting the established goals for water efficiency. An action plan with specific goals, timelines, and staff responsibilities for water efficiency updates should be established to implement all feasible opportunities.
6. **Track results and publicize successes**. Progress toward established water efficiency goals should be tracked and publicized as a means of highlighting successes and educating personnel on water efficiency. Successes should be acknowledged and awarded on a regular basis.

Case studies: strategic water management

Champion Baking Ingredients, a flour mill in Christchurch, New Zealand, embarked on a comprehensive water use reduction effort that included:

- the creation of a water efficiency team to monitor water efficiency and to implement water efficiency projects;
- the establishment of key performance indicators for water efficiency (litres/tonne of product produced), which are reported corporately each month; and
- promotional materials sent to staff that stress the importance of water efficiency.

Initiatives implemented in this effort led to a 22% reduction in facility water use (CCC 2010).

As part of its water reduction initiatives, Smith's Snackfood Company in Adelaide, Australia, tracks its water use carefully. The company has installed water meters to monitor the water used by individual production processes. These meters are read on a daily basis by the production crews themselves, and any abnormal increases of water use are investigated. Additionally, staff training in water efficiency has reportedly led to a broader understanding of plant operations, and, thus, a smoother running plant (OCETA 2012).

Good housekeeping. A general housekeeping program for facility water systems can ensure that water supplies and end uses continue to operate at optimal efficiency and that potential maintenance issues are identified and addressed promptly. In general, good housekeeping for water efficiency involves the following actions (Envirowise 2001) (NCDNER 1998):

- Inspection of all water connections, piping, hoses, valves, and meters regularly for leaks, with prompt repair of leaks when found.
- Inspection and replacement of faulty valves and fittings.
- Switching off water sprays and hoses when not in use.
- Keeping spray nozzles free of dirt and scale.
- Installing water meters on equipment to better enable monitoring and reduction of water consumption.
- Disconnecting or removing redundant pipework.

Use of water efficient building fixtures. For building fixtures such as toilets, showers, and faucets, water efficient designs can be installed that lead to significant water savings. For example, low-flow toilets typically require only 1.6 gallons per flush, compared to 3.5 gallons per flush required for standard toilets (Galitsky et al. 2005). Additional options include low-flow shower heads, aerating faucets, self-closing faucets, and proximity sensing faucets that turn on and off automatically. For additional information on water-saving fixtures and appliances, visit the U.S. EPA's WaterSense website (U.S. EPA 2012j).

Case study: Good housekeeping

At the J.W. Lees and Company Brewery in Manchester, England, good housekeeping practices for water management reportedly saved the company $106,000 per year in water costs with first year investment costs of only $4,400 (Envirowise 1996).

Use of small diameter hoses. All applications of hoses should be assessed, and, where feasible, the smallest possible diameter hoses should be installed. Small diameter hoses provide a low flow, high pressure condition, which can reduce the volume of water required for a given task (Lom and Associates 1998).

Use of automated start/stop controls. For end uses of water with intermittent demand, sensors (e.g., photocells) can be employed to detect the presence of materials and to supply water only when it is required by the process. Such sensors will turn off water supplies automatically when not required and also during non-production periods, thereby saving water (European Commission 2006).

Reducing cooling tower bleed-off. Cooling tower "bleed-off" refers to water that is periodically drained from the cooling tower basin to prevent the accumulation of solids. Bleed-off volumes can often be reduced by allowing higher concentrations of suspended and dissolved solids in the circulating water, which saves water. The challenge is to find the optimal balance between bleed-off and makeup water concentrations (i.e., the concentration ratio) without forming scales, which reduces the energy efficiency. The water savings associated with this measure can be as high as 20% (Galitsky et al. 2005).

Case study: Reduced bleed-off

The Ventura Coastal Plant, a manufacturer of citrus oils and frozen citrus juice concentrates in Ventura County, California, was able to increase the concentration ratios of its cooling towers and evaporative coolers such that bleed-off water volumes were reduced by 50%. The water savings amounted to almost 5,200 gallons per day, saving the company $6,940 per year in water costs (CDWR 1994). With capital costs of $5,000, the simple payback period was estimated at around seven months.

High pressure low volume sprays. In applications such as truck, container, surface, and floor cleaning, total water consumption can be reduced by using high pressure low volume spray systems, which employ small diameter hoses and/or flow restricting spray nozzles. Such systems can also be fitted with manual triggers, which allow personnel to regulate use, or automatic shut-off valves to further reduce water consumption (European Commission 2006, RACCP 2001).

Low pressure foam cleaning. Traditionally, walls, floors, and some equipment are cleaned using brushes, high pressure spray hoses, and detergents. Low pressure foam cleaning methods, in which cleaning foam is sprayed on surfaces and allowed to settle for 10 to 20 minutes before rinsing with low pressure water, can save both water and energy compared to high pressure cleaning methods (RACCP 2001, European Commission 2006). However, this method does not provide scouring ability and thus might not be a feasible replacement for all high pressure cleaning applications.

Pre-soaking of floors and equipment. An effective means of reducing water consumption in cleaning is to pre-soak soiled surfaces on floors and open equipment prior to cleaning. Pre-soaking can be effective at loosening dirt and hardened food residues so that less water is required in the actual cleaning operations (European Commission 2006).

8 Summary

By increasing energy efficiency, companies can reduce costs and increase predictable earnings in the face of ongoing energy price volatility. Considering energy price volatility and recent sharp increases in natural gas prices across the nation, energy efficiency improvements are needed today more than ever. Many companies have already accepted the challenge to improve their energy efficiency in the face of high energy costs and have begun to reap the rewards of energy efficiency investments. In addition, companies are turning to energy-efficient processes and technologies to reduce their criteria pollutant and carbon emissions, to meet corporate environmental goals.

This Energy Guide has summarized many energy-efficient technologies and practices that are proven, cost-effective, and available for implementation today. These opportunities are applicable at the component, process, facility, and organizational levels. Preliminary estimates of savings in energy and energy-related costs have been provided for many of the measures, based on case study data from real-world industrial applications. Typical investment payback periods and references to further information have been provided, where available.

To be successful, establish a focused and strategic energy management program that helps you identify and implement energy efficiency measures and practices across your organization and ensure continuous improvement. Then assess your company's energy-using systems and identify areas for improvement. Keep in mind that although the expected savings associated with some of the individual measures may be relatively small, their cumulative effect across an entire facility may be quite large. Many measures have relatively short payback periods and are therefore attractive economic investments on their own. The degree to which these measures are implemented will vary among plants and end uses, but continuous evaluation of your facility's energy profile will help to identify further cost savings over time. For all of the energy efficiency measures presented in this guide, research their economics and applicability to your facility's own unique production practices to assess the feasibility and potential benefits of each measure's implementation .

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Appendix A: Basic Energy Efficiency Actions for Plant Personnel

Personnel at all levels should be aware of energy use and organizational goals for energy efficiency. Staff should be trained in both skills and general approaches to energy efficiency in day-to-day practices. In addition, performance results should be regularly evaluated and communicated to all personnel, recognizing high achievement. Some examples of simple tasks employees can do are outlined below (Caffal 1995).

- Eliminate unnecessary energy consumption by equipment. Switch off motors, fans, and machines when they are not being used, especially at the end of the working day or shift, and during breaks, when it does not affect production, quality, or safety. Similarly, turn on equipment no earlier than needed to reach the correct settings (temperature, pressure) at the start time.

- Switch off unnecessary lights; rely on daylighting whenever possible.

- Use weekend and night setbacks on HVAC in offices or air conditioned buildings.

- Report leaks of water (both process water and dripping taps), steam, and compressed air. Ensure they are repaired quickly. The best time to check for leaks is a quiet time like the weekend.

- Look for unoccupied areas being heated or cooled, and switch off heating or cooling.

- Check that heating controls are not set too high or cooling controls set too low. In this situation, windows and doors are often left open to lower temperatures instead of lowering the heating.

- Check to make sure the pressure and temperature of equipment is not set too high.

- Prevent drafts from badly fitting seals, windows and doors, and hence, leakage of cool or warm air.

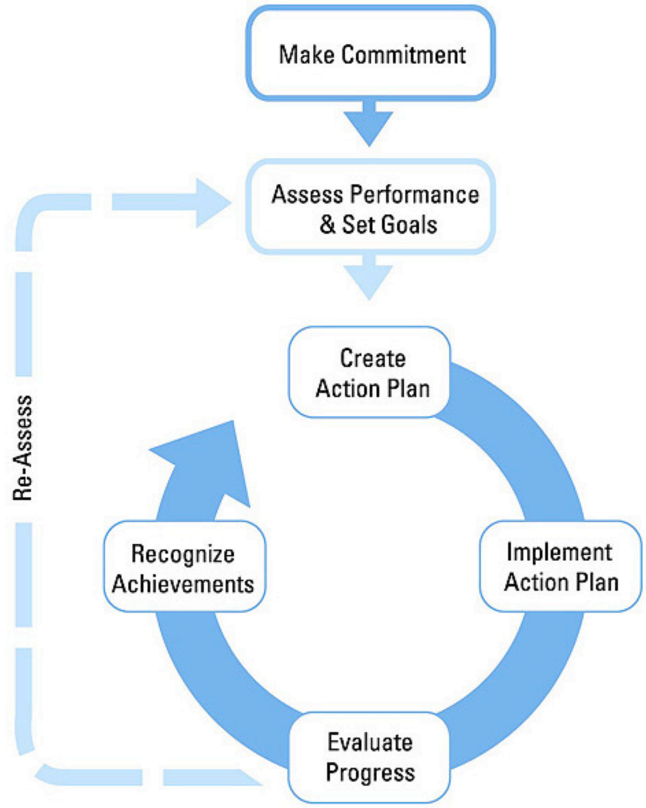
- Carry out regular maintenance of energy-consuming equipment.

- Ensure that the insulation on process heating equipment is effective.

Appendix B: ENERGY STAR Energy Management Matrix

The U.S. EPA has developed guidelines for establishing and conducting an effective energy management program based on the successful practices of ENERGY STAR partners.

These guidelines, illustrated in the graphic, are structured on seven fundamental management elements that encompass specific activities.



This assessment matrix on the following page is designed to help organizations and energy managers compare their energy management practices to those outlined in the Guidelines for Energy Management. The full guidelines can be viewed on the ENERGY STAR (EPA, 2012a).

How To Use The Assessment Matrix
The matrix outlines the key activities identified in the ENERGY STAR Guidelines for Energy Management and three levels of implementation:

- Where there is no evidence
- Where some elements of a program are in place
- Where an energy management program is fully implemented

To use apply this tool to your organization, follow these steps:

1. Print the assessment matrix.
2. Compare your program to the guidelines by identifying the degree of implementation that most closely matches your organization's program.
3. Use a highlighter to fill in the cell that best characterizes the level of implementation of your program. You will now have a visual comparison of your program to the elements of the ENERGY STAR Guidelines for Energy Management.
4. Identify the steps needed to fully implement the energy management elements and record these in the Next Steps column.

ENERGY STAR® Facility Energy Management Assessment Matrix

Company Name: Assessment Date:

	Little or no evidence	Some elements/degree	Fully implemented	Next Steps
Commit to Continuous Improvement				
Site Energy Leader	None assigned.	Assigned responsibilities but not empowered. 20-40% of time is devoted to energy.	Recognized and empowered leader having site manager and senior energy manager support.	
Site Energy Champion	None identified.	Senior manager implicitly supports the energy program.	Senior manager actively supports the energy program and promotes energy efficiency in all aspects of site operations.	
Site Energy Team	No site energy team.	Informal organization with sporadic activity.	Active cross-functional team guiding site energy program.	
Energy Policy	No energy policy or awareness of organizational policy.	Organizational policy in place. Little awareness by site energy team and limited application of policy.	Organizational policy supported at site level. All employees aware of goals and responsibilities.	
Site Energy Plan	No written plan.	Informal plan not widely known.	Written formal plan endorsed, distributed, and verified.	
Accountability	No energy budgeting and accountability.	Estimates used for allocating energy budgets.	Key users are metered separately. Each entity has total accountability for their energy use.	
Participation Levels	No reporting of energy performance data internally or involvement in external organizations.	Some participation, sharing, mentoring, and professional memberships. Annual reporting of performance.	Participates in energy network/organizations. Shares best practices/mentors other sites. Reports usage quarterly.	
Assess Performance and Opportunities				
Track & Analyze Data	Limited metering or tracking. No demand analysis or billing evaluation.	Some metering, tracking, analyzing, and reporting. Energy bills verified for accuracy.	Key loads metered, tracked, analyzed, and reported. Facility peak demand analyzed. Adjusts for real-time demand.	
Documentation	No manuals, plans, designs, drawings, specs, etc. for building and equipment available.	Some documentation and records available. Some review of equipment commissioning specs conducted.	Critical building and equipment documentation available and used for load surveys/recommissioning/efficiency goals.	

Benchmarking	Energy performance of systems and facilities not benchmarked.	Limited comparisons of specific functions, or only same-site historical comparisons.	Key systems/sites benchmarked using comparison tools like Portfolio Manager/Energy Performance Indicators.		
Technical Assessments	No formal or external reviews.	Limited review by vendors, location, or organizational and corporate energy managers.	Extensive regular reviews by multi-functional team of internal and external professionals. Full assessment every 5 years.		
Best Practices	None identified.	Ad hoc or infrequent monitoring of trade journals, internal databases, and other facilities' best practices.	Regular monitoring of trade journals, internal databases, and other facilities. Best practices shared and implemented.		
Set Performance Goals					
Goals/Potential	Energy reduction goals not established.	Loosely defined. Little awareness of energy goals by others outside of site energy team.	Potential defined by experience or assessments. Goals roll up to unit/site/ organization and status posted prominently.		
Career Development	No career development. No opportunities available.	Exposure to other energy programs. Some temporary or project assignments available elsewhere.	Energy professionals have established career paths that are reviewed annually. Opportunities for growth encouraged.		
Energy Team Incentives	No ties between energy efficiency improvement and compensation.	Spot awards or luncheons for employees on a project.	Accountability tied to performance reviews, compensation, and personal and plant bonuses.		
Create Action Plan					
Improvement Planning	No upgrade plan.	Upgrades implemented sporadically. Some compliance with organizational goals and standards.	Upgrade plans established; reflect assessments. Full compliance with organizational EE design guidelines and goals.		
Roles and Resources	Not addressed, or addressed on ad hoc basis only.	Informal interested person competes for funding. Little support from organizational program.	Internal/external roles defined and funding identified. Organizational or corporate program support secured.		
Site Planning Integration	Impact on energy from changes not considered.	Decisions impacting energy considered on first-cost basis only.	Projects/contracts include energy analysis. Energy projects evaluated with other investments. Lifecycle costing applied.		
Implement Action Plan					
Communication Plan	Site plan not developed.	Periodic communications for projects. Some reporting of energy use information.	All stakeholders are addressed on regular basis.		
Energy Awareness	None conducted.	Occasional energy efficiency awareness campaigns. Some communication of energy costs.	Planned outreach and communications. Support organizational initiatives. Employees aware of site energy costs.		

Building Staff Capacity	No training offered.	Some vendor training for key individuals and operators.	Broad training/certification in technology and best practices. Networking opportunities actively pursued.		
Contract Management	Contracts are renewed automatically without review.	Occasional review of supplier contracts.	Energy-efficient procurement policy in place. Vendors for replacements on standby. Regular review of suppliers.		
Incentives and Rebates	Not researched or pursued.	Occasional communication with utility representatives. Limited knowledge of incentive programs.	Researches rebates and incentives offered regionally and nationally. Communicates often with utility representatives.		
Evaluate Progress					
Measuring Results	No reviews.	Historical comparisons. Some reporting of results.	Compare usage & costs vs. goals, plans, other sites. Results reported to site and organizational or corporate management.		
Reviewing Action Plan	No reviews.	Informal check on progress.	Revise plan based on results, feedback and business factors. Best practices shared with other sites / organization or corporate program.		
Recognize Achievements					
Site Recognition	Not addressed.	Occasional recognition of projects and people.	Recognition system in place. Awards for projects pursued by operators.		
Organizational Recognition	Not sought.	Occasionally when prompted by senior management.	Senior management acknowledges site successes.		
External Recognition	Not sought.	Occasional trade magazine and vendor recognition.	Government and third-party recognition highlighting achievements sought. ENERGY STAR label for facility awarded annually.		

Appendix C: Support Programs for Industrial Energy Efficiency Improvement

This appendix provides a list of energy efficiency support available to industry. A brief description of the program or tool is given, as well as information on its target audience and the URL for the program. Included are federal and state programs. Use the URL to obtain more information from each of these sources. An attempt was made to provide as complete a list as possible; however, information in this listing may change with the passage of time.

Tools for Self-Assessment

Steam System Assessment Tool
Description: Software package to evaluate energy efficiency improvement projects for steam systems. It includes an economic analysis capability.
Target Group: Any industry operating a steam system
Format: Downloadable software package (13.6 MB)
Contact: U.S. Department of Energy
URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

Steam System Scoping Tool
Description: Spreadsheet tool for plant managers to identify energy efficiency opportunities in industrial steam systems.
Target Group: Any industrial steam system operator
Format: Downloadable software (Excel)
Contact: U.S. Department of Energy
URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

3E Plus: Optimization of Insulation of Boiler Steam Lines
Description: Downloadable software to determine whether boiler systems can be optimized through the insulation of boiler steam lines. The program calculates the most economical thickness of industrial insulation for a variety of operating conditions. It makes calculations using thermal performance relationships of generic insulation materials included in the software.
Target Group: Energy and plant managers
Format: Downloadable software
Contact: U.S. Department of Energy
URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

MotorMaster+
Description: Energy-efficient motor selection and management tool, including a catalog of over 20,000 AC motors. It contains motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting, and environmental reporting capabilities.
Target Group: Any industry
Format: Downloadable software (can also be ordered on CD)
Contact: U.S. Department of Energy

URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

ASDMaster: Adjustable Speed Drive Evaluation Methodology and Application

Description: Software program helps to determine the economic feasibility of an adjustable speed drive application, predict how much electrical energy may be saved by using an ASD, and search a database of standard drives.
Target Group: Any industry
Format: Software package (not free)
Contact: Electric Power Research Institute (EPRI), (800) 832-7322
URL: http://www.epri-peac.com/products/asdmaster/asdmaster.html (last accessed: December 28, 2012)

The 1-2-3 Approach to Motor Management

Description: A step-by-step motor management guide and spreadsheet tool that can help motor service centers, vendors, utilities, energy-efficiency organizations, and others convey the financial benefits of sound motor management.
Target Group: Any industry
Format: Downloadable Microsoft Excel spreadsheet
Contact: Consortium for Energy Efficiency (CEE), (617) 589-3949
URL: http://www.motorsmatter.org/tools/123approach.html (last accessed: December 28, 2012)

AirMaster+: Compressed Air System Assessment and Analysis Software

Description: Modeling tool that maximizes the efficiency and performance of compressed air systems through improved operations and maintenance practices
Target Group: Any industry operating a compressed air system
Format: Downloadable software
Contact: U.S. Department of Energy
URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

Fan System Assessment Tool (FSAT)

Description: The Fan System Assessment Tool (FSAT) helps to quantify the potential benefits of optimizing a fan system. FSAT calculates the amount of energy used by a fan system, determines system efficiency, and quantifies the savings potential of an upgraded system.
Target Group: Any user of fans
Format: Downloadable software
Contact: U.S. Department of Energy
URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

Combined Heat and Power Application tool (CHP)

Description: The Combined Heat and Power Application Tool (CHP) helps industrial users evaluate the feasibility of CHP for heating systems such as fuel-fired furnaces, boilers, ovens, heaters, and heat exchangers.
Target Group: Any industrial heat and electricity user
Format: Downloadable software
Contact: U.S. Department of Energy

URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

Pump System Assessment Tool 2004 (PSAT)

Description: The tool helps industrial users assess the efficiency of pumping system operations. PSAT uses achievable pump performance data from Hydraulic Institute standards and motor performance data from the MotorMaster+ database to calculate potential energy and associated cost savings.

Target Group: Any industrial pump user

Format: Downloadable software

Contact: U.S. Department of Energy

URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

Quick Plant Energy Profiler

Description: The Quick Plant Energy Profiler, or Quick PEP, is an online software tool provided by the U.S. Department of Energy to help industrial plant managers in the United States identify how energy is being purchased and consumed at their plant and also identify potential energy and cost savings. Quick PEP is designed so that the user can complete a plant profile in about an hour. The Quick PEP online tutorial explains what plant information is needed to complete a Quick PEP case.

Target Group: Any industrial plant

Format: Online software tool

Contact: U.S. Department of Energy

URL: http://www1.eere.energy.gov/industry/bestpractices/software.html (last accessed: December 28, 2012)

ENERGY STAR Portfolio Manager

Description: Online software tool helps to assess the energy performance of buildings by providing a 1-100 ranking of a building's energy performance relative to the national building market. Measured energy consumption forms the basis of the ranking of performance.

Target Group: Any building user or owner

Format: Online software tool

Contact: U.S. Environmental Protection Agency

URL: http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager (last accessed: December 28, 2012)

Assessment and Technical Assistance

Industrial Assessment Centers

Description: Small- to medium-sized manufacturing facilities can obtain a free energy and waste assessment. The audit is performed by a team of engineering faculty and students from 30 participating universities in the U.S. and assesses the plant's performance and recommends ways to improve efficiency.

Target Group: Small- to medium-sized manufacturing facilities with gross annual sales below $75 million and fewer than 500 employees at the plant site.

Format: A team of engineering faculty and students visits the plant and prepares a written report with energy efficiency, waste reduction and productivity recommendations.

Contact: U.S. Department of Energy
URL: http://www1.eere.energy.gov/industry/bestpractices/iacs.html (last accessed: December 28, 2012)

Manufacturing Extension Partnership (MEP)

Description:	MEP is a nationwide network of not-for-profit centers in over 400 locations providing small- and medium-sized manufacturers with technical assistance. A center provides expertise and services tailored to the plant, including a focus on clean production and energy-efficient technology.
Target Group:	Small- and medium-sized plants
Format:	Direct contact with local MEP Office
Contact:	National Institute of Standards and Technology, (301) 975-5020
URL:	http://www.mep.nist.gov/ (last accessed: December 28, 2012)

Small Business Development Center (SBDC)

Description:	The U.S. Small Business Administration (SBA) administers the Small Business Development Center Program to provide management assistance to small businesses through 58 local centers. The SBDC Program provides counseling, training and technical assistance in the areas of financial, marketing, production, organization, engineering and technical problems and feasibility studies, if a small business cannot afford consultants.
Target Group:	Small businesses
Format:	Direct contact with local SBDC
Contact:	Small Business Administration, (800) 8-ASK-SBA
URL:	http://www.sba.gov/sbdc/ (last accessed: December 28, 2012)

ENERGY STAR – Selection and Procurement of Energy-Efficient Products for Business

Description:	ENERGY STAR identifies and labels energy-efficient office equipment. Look for products that have earned the ENERGY STAR. They meet strict energy efficiency guidelines set by the EPA. Office equipment included such items as computers, copiers, faxes, monitors, multifunction devices, printers, scanners, transformers and water coolers.
Target Group:	Any user of labeled equipment.
Format:	Website
Contact:	U.S. Environmental Protection Agency
URL:	http://www.energystar.gov/index.cfm?c=business.bus_index (last accessed: December 28, 2012)

Training

ENERGY STAR

Description:	As part of ENERGY STAR's work to promote superior energy management systems, energy managers for the companies that participate in ENERGY STAR are offered the opportunity to network with other energy managers in the partnership. The networking meetings are held monthly and focus on a specific strategic energy management topic to train and strengthen energy managers in the development and implementation of corporate energy management programs.

Target Group: Corporate and plant energy managers
Format: Web-based teleconference
Contact: Climate Protection Partnerships Division, U.S. Environmental Protection Agency
URL: http://www.energystar.gov/ (last accessed: December 28, 2012)

Best Practices Program

Description: The U.S. DOE Best Practices Program provides training and training materials to support the efforts of the program in efficiency improvement of utilities (compressed air, steam) and motor systems (including pumps). Training is provided regularly in different regions. One-day or multi-day trainings are provided for specific elements of the above systems. The Best Practices program also provides training on other industrial energy equipment, often in coordination with conferences.
Target Group: Technical support staff, energy and plant managers
Format: Various training workshops (one day and multi-day workshops)
Contact: Office of Industrial Technologies, U.S. Department of Energy
URL: http://www1.eere.energy.gov/industry/bestpractices/training.html (last accessed: December 28, 2012)

Compressed Air Challenge®

Description: The not-for-profit Compressed Air Challenge® develops and provides training on compressed air system energy efficiency via a network of sponsoring organizations in the United States and Canada. Three levels of training are available: (1) Fundamentals (1 day); (2) Advanced (2 days); and (3) Qualified Specialist (3-1/2 days plus an exam). Training is oriented to support implementation of an action plan at an industrial facility.
Target Group: Compressed air system managers, plant engineers
Format: Training workshops
Contact: Compressed Air Challenge: Info@compressedairchallenge.org
URL: http://www.compressedairchallenge.org/ (last accessed: December 28, 2012)

Financial Assistance

Below major federal programs are summarized that provide assistance for energy efficiency investments. Many states also offer funds or tax benefits to assist with energy efficiency projects (see below for State Programs). However, these programs can change over time, so it is recommended to review current policies when making any financial investment decisions.

Industries of the Future - U.S. Department of Energy

Description: Collaborative R&D partnerships in nine vital industries. The partnership consists of the development of a technology roadmap for the specific sector and key technologies, and cost-shared funding of research and development projects in these sectors.
Target Group: Nine selected industries: agriculture, aluminum, chemicals, forest products, glass, metal casting, mining, petroleum and steel.
Format: Solicitations (by sector or technology)
Contact: U.S. Department of Energy – Office of Industrial Technologies

URL: http://www.eere.energy.gov/industry/technologies/industries.html (last accessed: December 28, 2012)

Inventions & Innovations (I&I)

Description:	The program provides financial assistance through cost-sharing of 1) early development and establishing technical performance of innovative energy-saving ideas and inventions (up to $75,000) and 2) prototype development or commercialization of a technology (up to $250,000). Projects are performed by collaborative partnerships and must address industry-specified priorities.
Target Group:	Any industry (with a focus on energy-intensive industries)
Format:	Solicitation
Contact:	U.S. Department of Energy – Office of Industrial Technologies
URL:	http://www.eere.energy.gov/inventions/ (last accessed: December 28, 2012)

Small Business Administration (SBA)

Description:	The Small Business Administration provides several loan and loan guarantee programs for investments (including energy-efficient process technology) for small businesses.
Target Group:	Small businesses
Format:	Direct contact with SBA
Contact:	Small Business Administration
URL:	http://www.sba.gov/ (last accessed: December 28, 2012)

State and Local Programs

The federal government, as well as many state and local governments have general industry and business development programs that can be used to assist businesses in assessing or financing energy-efficient process technology or buildings. Please contact your state and local government to determine what tax benefits, funding grants, or other assistance they may be able to provide your organization. In addition, many utilities and energy providers have incentive programs to encourage efficiency improvements and renewable energy use. Contact your energy provider for incentives that can apply to your facility.

For a comprehensive list of federal and state incentives, please visit the Database of State Incentives for Renewables and Efficiency (DSIRE 2012).

Appendix D: Teaming Up to Save Energy Checklist

The following checklist can be used as a handy reference to key tasks for establishing and sustaining an effective energy team. For more detailed information on energy teams, consult the U.S. EPA's *Teaming Up to Save Energy* guide (EPA, 2012a).

ORGANIZE YOUR ENERGY TEAM		√
Energy Director	Able to work with all staff levels from maintenance to engineers to financial officers. Senior-level person empowered by top management support	
Senior Management	Energy director reports to senior executive or to a senior management council. Senior champion or council provides guidance and support	
Energy Team	Members from business units, operations/engineering, facilities, and regions. Energy networks formed. Support services (PR, IT, HR).	
Facility Involvement	Facility managers, electrical personnel. Two-way information flow on goals and opportunities. Facility-based energy teams with technical person as site champion.	
Partner Involvement	Consultants, vendors, customers, and joint venture partners. Energy savings passed on through lower prices.	
Energy Team Structure	Separate division and/or centralized leadership. Integrated into organization's structure and networks established.	
Resources & Responsibilities	Energy projects incorporated into normal budget cycle as line item. Energy director is empowered to make decisions on projects affecting energy use. Energy team members have dedicated time for the energy program.	
STARTING YOUR ENERGY TEAM		√
Management Briefing	Senior management briefed on benefits, proposed approach, and potential energy team members.	
Planning	Energy team met initially to prepare for official launch.	
Strategy	Energy team met initially to prepare for official launch.	
Program Launch	Organizational kickoff announced energy network, introduced energy director, unveiled energy policy, and showcased real-world proof.	
Energy Team Plans	Work plans, responsibilities, and annual action plan established.	
Facility Engagement	Facility audits and reports conducted. Energy efficiency opportunities identified.	

BUILDING CAPACITY		√
Tracking and Monitoring	Systems established for tracking energy performance and best practices implementation.	
Transferring Knowledge	Events for informal knowledge transfer, such as energy summits and energy fairs, implemented.	
Raising Awareness	Awareness of energy efficiency created through posters, intranet, surveys, and competitions.	
Formal Training	Participants identified, needs determined, training held. Involvement in ENERGY STAR Web conferences and meetings encouraged. Professional development objectives for key team members.	
Outsourcing	Use of outside help has been evaluated and policies established.	
Cross-Company Networking	Outside company successes sought and internal successes shared. Information exchanged to learn from experiences of others.	
SUSTAINING THE TEAM		√
Effective Communications	Awareness of energy efficiency created throughout company. Energy performance information is published in company reports and communications.	
Recognition and Rewards	Internal awards created and implemented. Senior management is involved in providing recognition.	
External Recognition	Credibility for your organization's energy program achieved. Awards from other organizations have added to your company's competitive advantage.	
MAINTAINING MOMENTUM		√
Succession	Built-in plan for continuity established. Energy efficiency integrated into organizational culture.	
Measures of Success	Sustainability of program and personnel achieved. Continuous improvement of your organization's energy performance attained.	