Brewers Association

Energy Usage, GHG Reduction, Efficiency and Load Management Manual

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acknowledgements

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introduction

Craft brewers are an innovative segment of the greater brewing industry. It's no surprise that many craft brewers have discovered innovative solutions for energy usage and GHG reduction opportunities at their facilities. Considering the rising energy costs of today, reducing energy usage should be a high priority at all breweries.

Owners and operators may consider energy costs as an expense they cannot control, and that it only rises and falls with the price of energy in the area. Depending on these costs, energy reduction may not be a top priority within brewery operations, but breweries that do not pay attention to the opportunities at all levels of their operations may miss out on potential cost saving and revenue generating measures. There are many best practices for energy efficiency and conservation that can be easily incorporated into daily operations, as well as solutions that can reach beyond greenhouse gas (GHG) reduction and lead to operating cost reductions, additional sources of income, and new community initiatives. These solutions help brewers save money and become industry leaders in sustainable practices.

This manual is a consolidated resource for effective energy management and greenhouse gas reduction solutions in the craft brewers segment. Solutions outlined can apply to all breweries, regardless of location and operational size. Guidance is provided for brewers that are just beginning to explore energy management and GHG reduction programs, as well as for brewers that are looking to improve a well established program.

In addition, there are checklists, resource lists, and other visual tools throughout the manual and in Appendix A to help breweries make decisions about energy efficiency and GHG reduction opportunities.

Disclaimer: the following information provided constitute suggestions that may or may not fit the need of each brewery specifically. Brewers should proceed with caution when implementing any new programs. It is not guaranteed that operating under the guidance of this manual will lead to any particular outcome or result.

The information presented is a pathway to effective and sustainable energy and GHG management from start to finish. This information is organized into five sections:

1. **Segment Profile:** A discussion of energy usage and GHG generation, where to find information on regulatory drivers, examples of non-regulatory drivers, and risks and opportunities for cost savings.
2. **Data Management:** A guide to identifying the components of brewery energy usage, establishing key performance indicators and goals, managing energy and carbon footprint data, and benchmarking energy efficiency and GHG reduction progress toward goals.
3. **Best Practices:** Guidance on best practices to conserve energy and reduce GHG emissions within the craft brewers segment with a focus on opportunities in the brewing process, packaging, warehousing, utilities, and food service/events.
4. **Onsite Energy Reduction:** An overview of drivers for onsite energy and GHG reduction and example projects.
5. **Case Studies:** Examples of successful energy management and GHG reduction programs used by craft brewers.

section one

Sector Profile – Energy Use in Breweries

Energy is an operating cost that often gets treated either as a necessary evil, or, at worst, it is ignored all together. Energy, in its various forms, touches all areas of the brewing business. Understanding just how energy is used throughout the operation can turn a perceived necessary evil into a competitive advantage.

The intent of this section is to outline how energy is profiled within a brewery and brewpub. Knowing and understanding how energy is used and where the largest users reside will provide a first step in managing energy costs. This leads to improved efficiency that will allow for long-term cost savings, lower GHG emissions, and improved competitive position.

Energy usage in breweries varies depending on size, location, and product. Refrigeration generally creates the largest electrical load, while brewing consumes the largest amount of natural gas (used for heat). Below are graphs that illustrate the percentage of energy used throughout the operation.

Energy usage also varies among brewpub operations. Food preparation and Heating Ventilating and Air Conditioning (HVAC) consume the greatest amount of energy.

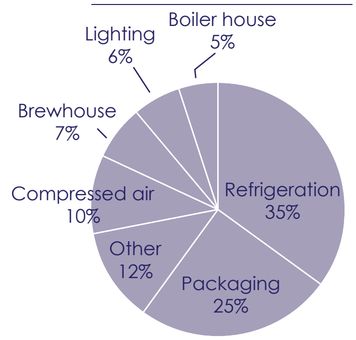
1.1 Overview of Current Energy Use/ Greenhouse Gas Performance and Trends

Energy used in a brewery breaks down into two primary units. Thermal energy in the form of natural gas is used to generate hot water and steam, which is then used in brewing, packaging and general building heating. Electrical energy is used to power all equipment, with the largest user being refrigeration. Thermal sources average 70% of the energy

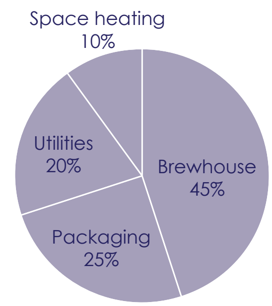
Energy Consumption In Breweries (All Sizes)

Data from the U.S. Environmental Protection Agency (EPA) show that refrigeration, packaging and compressed aire consume 70% of U.S. breweries' electricity use (A), whereas the brewhouse dominates natural gas and coal use at 45 percent (B).

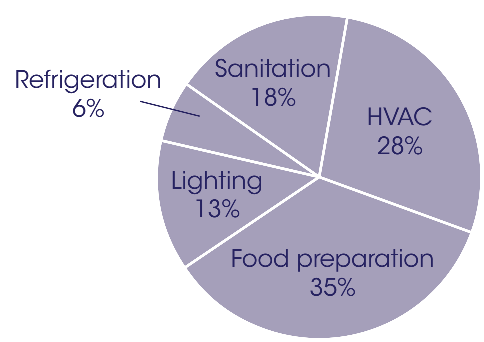
A. Electricity



B. Natural gas



Energy Consumption Within The Food Service Environment (Ifma 2009)



© E Source; data from the U.S. Environmental Protection Agency

consumed in the brewery; however, it usually only accounts for 30% of the actual energy cost. Based on this, efforts to reduce electrical energy should be given top priority when considering energy reduction opportunities, as they account for the largest opportunity.

The following table shows the average kWh/BBL ranges for breweries of all sizes. In general, smaller breweries have higher kWh/BBL numbers because their smaller volumes do not offset the base energy required to brew a barrel of beer. The kWh/BBL represents the amount of energy used to produce one barrel of beer. In real terms, at a cost of 6 cents per kWh, the total cost for the numbers listed below would be $3.30 to $4.26 per barrel produced. This information provides details into the actual cost of energy and provides real time insight to the operating cost impacts if the kWh/BBL changes month to month or if the cost for energy changes.

Average Relative Energy Use

Electrical Usage	12 to 22 kWh/bbl
Thermal (Natural Gas)	1.3 to 1.5 Therms/bbl
Combined	50 to 66 kWh/bbl

1.2 Regulatory Drivers

Energy profiles are not only influenced by day-to-day operations, but also by outside forces that influence the cost of doing business. In the energy world, those costs can be masked in the guise of regulatory requirements. Regulatory drivers focused on energy use can be subject to direct energy efficiency requirements or Greenhouse Gas Emissions (GHG) requirements that will have a direct impact on energy usage. Brewers need to take into account all state and local regulatory requirements connected to these two areas to fully understand the energy reduction potential within the brewery or brewpub.

The EPA Mandatory GHG accounting rule applies to facilities from specific industries that directly emit 25,000 metric tonnes of carbon dioxide equivalent or more per year. Assuming an average thermal requirement of 1.5 therms per barrel of production and an emission factor of 5.29 kg CO_2 emitted per therm, an average brewery would produce roughly 125 barrels of beer per metric ton of CO_2 emitted. It is unlikely that craft brewers under approximately 3 million barrels of annual production would be susceptible to this rule based on their size and operations. Naturally this threshold would change if the EPA accounting rule limit changed.

1.3 Non-Regulatory Drivers – Image/Brand, Community Ties

Non-regulatory drivers that impact energy usage and cost are in place today to assist all brewers with lowering energy usage and cost. These different programs are designed to provide guidance, tools, and management practices that will allow for the most efficient use of energy at the lowest cost possible. The programs are offered by both government agencies and the private sector, such as EPA Energy STAR, ISO50001, Green

Example Energy Efficiency Programs

ITEM	ENERGY STAR	ISO 50001
Governing Body	EPA	International Standards Organization
Commitment	Voluntary	Voluntary
Focus of Standard	Energy Efficiency / Energy Management guidelines for products and facilities	International Energy Management Standard for Industrial and Commercial facilities to manage energy
Focus Areas	• Energy Management • Data collection and tracking • Energy usage reduction • Communication and training	• Energy Measurement • Tracking and reporting management practices • Energy usage data collection • Standards for energy reduction systems and tools
Main Criteria	• Self-Managed • Energy manage program • 10% energy reduction over 3 yr period	• Adherence to ISO reporting, and verification standards • Energy Management program
Advantages	• Lower energy usage • Long-term energy cost savings • Established energy reduction practices	• International verified energy practice member • Aligns with ISO 9001 and ISO 14001 programs • Long term energy usage and cost management

Building and LEED, as well as through local environmental centers, such as the Chicago Center for Green Technology. These programs offer low-cost or no-cost information on improving energy efficiency and conservation, as well as how to develop and implement energy management programs. This information will help brewers continuously implement and develop energy efficient practices, resulting in lower operating costs and a lower carbon footprint.

Stakeholder recognition can be achieved through reporting initiatives, certifications, and achievement and innovation awards (such as Energy STAR, LEED, and Climate Action Leader).

Standing Stone Brewery "Sustainable Business Oregon" award

Standing Stone Brewery efforts have received recognition, including the State of Oregon Sustainability Award, Oregon Business "100 Best Green Businesses" and Sustainable Business Oregon's "Sustainable Business Innovation" award (Operations), as well as ongoing media spotlights.

Community ties give breweries the unique opportunity to promote energy efficiency and GHG reduction outside their facility walls, further supporting brand and image.

New Belgium Brewery FortZED

As part of the FortZED (Zero Energy District) project, Fort Collins, Colorado implemented a smart grid component of the city's "Zero Energy District" plan. Fort Collins has begun implementing a smart grid project with partners from the Fort ZED consortium. The New Belgium Brewery is one of the test sites. The proposal to implement the smart grid is an $11.2 million project with $6 million coming from a Department of Energy grant. Colorado State University will also take part in the pilot.

1.4 Risks and Opportunities – Energy/Greenhouse Gas Reduction

In the brewing sector, energy can be a large source of GHG emissions, regardless of whether it is produced onsite from combustion of fossil fuels or purchased from an electric provider. GHGs are also generated throughout the supply chain, from raw materials and packaging production to refrigeration, transportation of goods, and GHG emissions from waste (carbon footprint).

Many craft brewers are calculating their GHG emissions and have set targets to reduce them. When calculating a GHG inventory, there are three areas (or scopes) that brewers track:

- Scope 1: Direct emissions result from activities the brewery has direct control over. (e.g., combustion of fuel in an onsite boiler)
- Scope 2: Indirect emissions that the company cannot control, but are a direct result of brewery activities. (e.g., purchased electricity and steam)
- Scope 3: Other indirect emissions other than purchased electricity and steam. (e.g., GHG emitted during the production of packaging material). While brewers do not have control over how the packaging is produced, they can control where and which packaging is purchased.

There are many different reporting standards and protocols that help breweries calculate their emissions. Good resources include the BIER (Beverage Industry Environmental Roundtable) GHG emissions guidance, The Greenhouse Gas Protocol and the Publicly Available Specification 2050 (PAS 2050).

In the brewing industry, many of the processes that consume energy will also create GHG emissions. In most cases, energy reduction efforts will carry the additional benefit of GHG emissions reduction.

Case Studies

Boulevard Brewery installed a zone control strategy in the Building Automation System. This system makes heating and cooling adjustments based on real-time requirements in each zone, while leaving unoccupied, non-critical zones relaxed regarding their temperature requirements.

In 2004, Victory Brewing Company upgraded their brewhouse with a system that recovers much of the primary energy fueling it. Approximately one-third of the natural gas burned to heat and boil beer is retained in the system for heating purposes, enabling them to reduce GHG emissions.

There are many different ways breweries can reduce their GHG emissions. Once the facility has conducted a greenhouse gas emission inventory, their greatest sources of emission can be identified and the necessary improvements can be made.

section two

Data Management

As discussed in Section 1, regardless of the size of the brewery, knowing where the brewery currently stands is the first step in understanding what direction to take. Understanding the current energy profile and balance of the operation along with collecting metrics on energy usage will allow brewers to start the journey on energy reduction without spending one dollar on capital projects.

Data management is more than just a component of a successful program; it is a necessity for a successful business strategy. As discussed previously, there are both risks and opportunities in energy and GHG reduction management. Making informed business decisions to minimize risk and maximize opportunity requires effective data management.

Effective Data Management System

This section covers best practices in data management, from establishing a data collection routine and ensuring the data is accurate, to creating key performance indicators and setting goals. If followed, this information can result in energy consumption and cost reduction on a continual basis at a spending level that will fit within the brewer's budget.

2.1 Data Collection

Measurement Is the Key

The most important step in energy management and conservation is measuring and accounting for energy consumption.

The best-kept secret within the energy world is that the most important energy efficiency, conservation, or reduction opportunity that can be installed at a brewery or brewpub is an energy data and tracking program. Installing high efficiency lighting, heat recovery, and energy star equipment are good practices that will lower energy usage and cost. When these saving opportunities are combined with an energy management program, continual long-term reductions in kWh usage and cost will be achieved. Managing the energy data will prevent the savings that are achieved by capital projects and operation practices from being maintained.

Energy data can be as simple as collecting and analyzing monthly gas and electric bills, to using energy management systems that use meters and software to track energy usage. Typically, the more data available, higher degrees of analysis can be performed, which can result in higher reduction amounts. Even though each brewer is unique, each brewery shares in one common thing when it comes to energy usage – each receives an energy bill. These bills form the foundation for all energy data collection and tracking programs. It is from these statements that the energy data tree will be developed.

Below are examples of different energy data levels that can be incorporated at a given facility. The size of the facility and its power consumption along with financial and human resources will determine what type of energy data collection and tracking program should be installed.

Level 1 data collection involves the following tasks:

- Collecting energy bills monthly
- Tracking data in a spreadsheet
- Graphing data from electric bills, gas bills and produced barrels

Level 2 data collection involves the following tasks:

- All Level 1 tasks
- Breaking down energy profile by area:
- Brewing (electrical and fuel kWh usage)
- Packaging (electrical and fuel kWh usage)
- Utility Support (electrical and fuel kWh usage)
- Warehouse (electrical and fuel kWh usage)
- Offices (electrical and fuel kWh usage)
- Brewpub/restaurant (electrical and fuel kWh usage)
- Additional metering (may be required for this level of data collection)

Level 3 data collection involves the conducting Level 1 and Level 2 tasks at the following specific locations within the process or equipment:

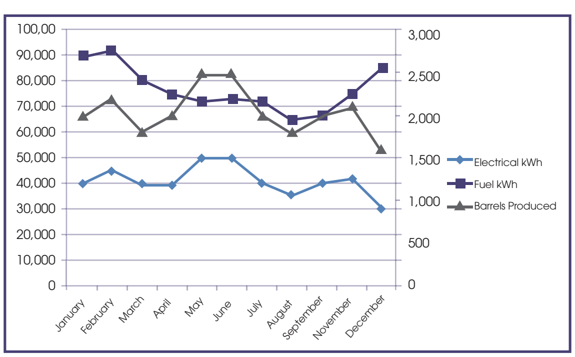
- Brew Line 1 (energy usage)
- Bottle Line 1 (energy usage)
- Draught line 2 (energy usage)
- Air compressor 1 (kWh usage)
- Boiler 1 (energy usage)
- Main office (energy usage)

Tabular Example of One Full Year of Data Collection

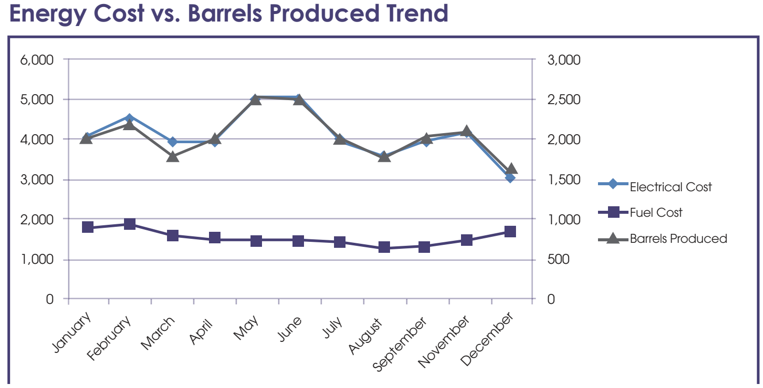
Item	January	February	March	April	May	June	July	August	Septem-ber	November	December	Totals
Electircal kWh	40,000	45,000	39,000	39,500	50,000	50,000	40,000	35,000	40,000	42,000	30,000	450,500
Fuel kWh	90,000	92,000	80,000	75,000	72,000	73,000	72,000	65,000	67,000	75,000	85,000	846,000
Elect Cost	$4,000	$4,500	$3,900	$3,950	$5,000	$5,000	$4,000	$3,500	$4,000	$4,200	$3,000	$45,050
Fuel Cost	$1,800	$1,840	$1,600	$1,500	$1,440	$1,460	$1,440	$1,300	$1,340	$1,500	$1,700	$16,920
Total Enegy Cost	$5,800	$6,340	$5,500	$5,450	$6,440	$6,460	$5,440	$4,800	$5,340	$5,700	$4,700	$61,970
Total Energy kWh	130,000	137,000	119,000	114,500	122,000	123,000	112,000	100,000	107,000	117,000	115,000	1,296,500

Data in this tabular format provides a visual reference of the brewery's energy usage and cost compared to the number of produced beer barrels. Data can be graphed to better trend and understand usage and cost data.

Energy Usage vs. Barrels Produced Trend



Energy Cost vs. Barrels Produced Trend



Sierra Nevada Sustainability Report, Energy Monitoring

To track energy consumption and generation at the facility, we installed an energy monitoring system called Green Energy Management Systems (GEMS) that monitors solar output, all four fuel cells, purchased electricity, and electricity sold back to the grid during overproduction period. Tracking energy production and consumption on a real time basis allows us to identify spikes and dips in consumption and be better prepared to minimize peak demand charges. In order to expand the benefits of monitoring, we plan to start monitoring large load use points within the plant to help with load shedding and shifting during peak hours when electricity is the most expensive.

We track electricity consumption by kWh consumed per barrel (BBL) of beer produced. One of the road blocks we face in our energy tracking program is that the entire Sierra Nevada campus—restaurant, CO_2 recover, waste water treatment facility, etc.—are all on the same electricity meter, making it very difficult to break out brewing energy consumption. However, in the last four years we have successfully reduced our overall electricity consumption while increasing production.

2.2 Ensuring Accuracy

After data measures for energy efficiency and GHG reductions are identified and quantified, the information should always be reviewed for accuracy. Without reliable data, especially as the starting point, it will be difficult to track progress. Having accurate initial data is also important to monitor for new energy efficiency opportunities and GHG reduction points, identify mid-point goal milestones, and cost savings.

To verify the data, three key questions are:

- Does the amount of energy used appear reasonable based on the amount of beer produced?
- Is the amount of energy consistent with historical usage (e.g., last month and the same time last year)?
- Is there any missing data that should be included (e.g., new bottle line)?

After the data are verified and approved, the information should be shared with team members (e.g. brewery employees, management, etc.). Breweries which have collected information for several years can report progress toward energy and GHG reduction goals and overall cost savings. For breweries new to energy management and GHG reduction programs and those well established in this area, it is always important to communicate both the starting point and the ultimate goals and targets it is aiming to achieve.

Management Tips When Measuring and Accounting For Energy Consumption

- *Consider developing meaningful energy performance indicators specific to your brewery's needs*
- *Conduct seminars or awareness sessions for all operators to explain:*
  - *The energy costs and the means of their control*
  - *The effect of good housekeeping on driving the energy costs down*
  - *The importance of proper operational practices*
- *Review the indicators regularly at operations management meetings*
- *Keep employees informed - communicate the results*
- *Use the energy cost results in developing and reviewing of business plans, alternate energy plans and capital projects*
- *Use the energy cost indicators as a management tool to improve performance*

Source: Canadian Brewers Association 2010 Energy Guide

2.3 Benchmarking – Key Performance Indicators (KPIs)

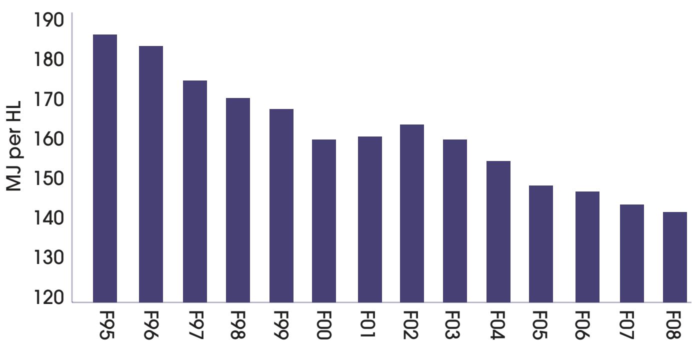
Collecting and ensuring accurate tracking of energy data will help operators and management teams understand the relationship between energy usage and costs and production, and month-to-month variances. To improve energy reduction efforts, breweries should develop a brewery culture that manages energy usage to Key Performance Indicators (KPIs). These KPIs should be developed and benchmarked at least monthly and annually. Monitoring of KPIs and corrective actions implemented from benchmark analysis will provide continuous low cost opportunities for lowering energy cost and carbon footprint.

The most important part of developing a KPI is determining its variables. The denominator is the variable that is intended to be reduced, while the numerator is expected to grow. In this particular manual, the denominator is kWh and numerator is the number of produced barrels of beer (BBL). This KPI (kWh/BBL produced) will allow operators to manage the energy intensity on a regular basis. As the goal is to lower kWh for BBL produced, the KPI demonstrates the brewery's success at lowering its energy levels.

For example, the calculation used to determine the main energy KPI is as follows:

Total kWh used / Total barrels produced = Energy Intensity Ratio

An example of successful energy reduction at a brewery is shown below:



Calculation of Cost Savings

- *At 49 kWh/BBL x 22,500 BBLS = 1,102,500 kWh/yr.*
- *At average total energy cost of $0.047/kWh the total cost = $51,817*
- *Potential savings: $61,970 - $51,817 = $10,153 or 17% of energy yearly cost*

This example shows the benefits of developing and tracking energy usage in comparison to barrels produced. Capturing 17% of savings on a consistent basis may not be practical due to weather conditions, equipment, product mix etc., however, the data provides a reference point and ideal goal. A potential next step could be to develop management techniques and goals that can be used to lower energy usage and capture a portion of the $10,153 savings.

A Level 1 energy data collection program performs the calculations above and benchmarks monthly energy intensity KPIs in order to lower energy usage and cost. Level 2 and Level 3 energy data collection programs may consider additional energy KPIs.

These examples outline additional KPIs that may be tracked and used to manage energy usage in brewery operations. Each brewer can develop specific KPIs to help manage their particular processes to improve energy efficiency and lower cost.

Energy Intensity

Using examples in Section 2.1 the following KPI information can be derived:

Item	January	February	March	April	May	June	July	August	Septem-ber	November	December	Totals
Electrical kWh	40,000	45,000	39,000	39,500	50,000	50,000	40,000	35,000	40,000	42,000	30,000	450,500
Fuel kWh	90,000	92,000	80,000	75,000	72,000	73,000	72,000	65,000	67,000	75,000	85,000	846,000
Total Enegry kWh	130,000	137,000	119,000	114,500	122,000	123,000	112,000	100,000	107,000	117,000	115,000	1,296,500
Barrels Produced	2,000	2,200	1,800	2,000	2,500	2,500	2,000	1,800	2,000	2,100	1,600	22,500

The KPI in the example above ranges from 49kWh/BBL to 72kWh/BBL. This data highlights potential savings that exist in the brewery's operations. Based on total annual energy cost of $61,970 and an annual production of 22,500 BBLs, the total energy cost per barrel is $2.74/BBL. ($61,970/22,500 BBLs = $2.74/BBL).

Additional KPIs to track

AREA	METRIC	METRIC
Brewhouse	kWh/BBL brewed	
Packaging	kWh/BBL packaged	kWh/Case
Refrigeration	kWh/ BBL shipped	kWh/kg
Steam System	kWh/BBL shipped	kWh/kg
Compressed Air	kWh/BBL shipped	kWh/cubic meters
Electrical Energy	kWh/BBL shipped	

Restaurants and brewpubs can also develop and use KPIs to manage energy usage. The denominator in most cases will depend on which variable will provide the best data for benchmarking. Examples of denominators for restaurants and brewpubs include:

- Hours of operation
- Total Sales
- Number of meals and drinks served
- Square footage (use if no other normalizer is available)

The denominator should be a consistent variable that changes over time. Based on typical energy usage in restaurants as described in Section 1, 60-70% of energy is used within HVAC and food prep. The best denominator to adjust for one or both of these variables may be the best choice for KPI or KPIs.

2.4 Guidelines For Setting Measurable Goals And Objectives

A good target or goal must be realistic and achievable. Energy affects all aspects of brewery business, making energy reduction goals difficult to set and implement. It is imperative to establish an energy management program that tracks energy usage to review if the brewery's energy reduction initiatives are achieving the target savings goals. The steps for developing short-term goals are:

- Establish an energy baseline across the facility.
- Determine a base year for data benchmarking.
- Decide how the goal will be tracked - in absolute energy usage reduction (kWh used) or normalized energy usage (kWh/BBL). Most breweries set targets for both metrics.
- Review energy baseline data with all team members involved in developing and implementing the energy reduction program.
- Prepare a list of energy practices and projects that can be used to help lower energy usage.
- Determine the potential impact savings will have on the baseline energy usage.
- Determine what percentage of reduction can be achieved as well as a stretch percentage to allow for innovation.
- Establish the goal.

Example Scenario

Based on discussion with operations, maintenance and finance it was determined that five separate energy reduction projects can be developed and implemented resulting in a 2% overall energy reduction. Operations reported that through best practices, employee training and procurement changes, an additional 1.5% reduction in energy can be achieved. Combining the two could result in a 3.5% energy savings overall.

Further discussion ensues and the team agrees to add 1% to the potential saving and establish an overall goal of 4.5% energy reduction for the upcoming fiscal year.

Examples Of Goal Setting

ENERGY EFFICIENCY GOAL	PROGRESS TO GOAL
Improve energy efficiency by 20% between 2006 and 2010 with 2005 as the baseline year.	Through 2008, energy efficiency has been improved by 19.2%.
Reduce the amount of electrical energy used by 5% from 2006 to 2010 using 2005 as the baseline year both on an absolute and normalized to square footage basis.	Electrical energy consumed per square foot has decreased by 22% between 2005 and 2008.
7% reduction in energy use corporate-wide by 2018 with a baseline year of 2003.	2.7% reduction corporate wide as of November 2008.
Reduce energy intensity by 2% per year through 2012 from 2001 base.	2012 goal was achieved in 2007, with a measure that was 23% below the 2001 base.
Achieve 50% reduction in energy usage by 2012 with a baseline of 2002.	Reduced total energy usage (both direct and indirect) by approximately 41% from the 2002 Baseline.

Establishing a long-term reduction follows a similar path, however these goals should account for business growth, capital availability, and external considerations. Long-term goals should be realistic and achievable, support short-term goals, and be flexible to meet business needs. Long-term goals should extend 3 to 5 years and develop periodic milestones to ensure that the target is being met. A benchmarking plan should be established based on brewery size, data maturity, etc. After the goal has been established, the target can be developed.

Managing the Energy Reduction Goal

- Involve employees to implement energy savings and conservation practices
- Develop and implement energy reduction projects envisioned to achieve goal
- Form an energy team with an energy champion and meet monthly to review the energy data and variances to the target
- Implement corrective actions if necessary
- Determine why any savings were achieved and if these actions can be permanent
- Give business conditions priority over energy program goals; however, by taking immediate corrective action, over time the brewery will reduce energy usage, employees will be more aware of how energy is used, and the program will become more efficient.

Tracking example

The example in Section 2.2 established an average energy intensity ratio of 58kWh/BBL using the short-term goal of 4.5% reduction.
A new monthly target can be established and used to track progress towards the goal.

FY2012

Item	January	February	March	April	May	June	July	August	Septem-ber	November	December	Totals
Electrical kWh	40,000	45,000	39,000	39,500	50,000	50,000	40,000	35,000	40,000	42,000	30,000	450,500
Fuel kWh	90,000	92,000	80,000	75,000	72,000	73,000	72,000	65,000	67,000	75,000	85,000	846,000
Total Energy kWh	130,000	137,000	119,000	114,500	122,000	123,000	112,000	100,000	107,000	117,000	115,000	1,296,500
Barrels Produced	2,000	2,200	1,800	2,000	2,500	2,500	2,000	1,800	2,000	2,100	1,600	22,500
Energy Intensity KPI (kWh/BBLs produced)	65	62	66	57	49	49	56	56	54	56	72	58

FY2013

Item	January	February	March	April	May	June	July	August	Septem-ber	November	December	Totals
Electrical kWh												
Fuel kWh												
Total Energy kWh												
Barrels Produced												
Energy Intensity KPI (kWh/BBLs produced) Actual												
Energy Intensity KPI (kWh/BBLs produced) Monthly Target	62	59	63	55	47	47	53	53	51	53	69	55

section three

Usage & Reduction Best Practices

This section will discuss opportunities within all brewery and restaurant operations that will help achieve energy reduction. The most important aspects of energy reduction processes are engaging in data collection systems that manage energy usage and engaging employees and customers with the brewery's energy efficiency and conservation culture. Employees and customers alike can experience the benefits of energy reduction in both their workplace and homes.

Within brewery and restaurant operations there are numerous opportunities to lower energy usage and cost. Defining, prioritizing, and implementing these opportunities can be an intimidating task. Follow the three steps below to get started:

1. Ensure that a data collection and tracking system is in place or being developed.

2. Define business case priorities for implementing energy savings opportunities:

3. Define and set a goal for energy reduction; communicate and engage all employees.

Potential energy reduction opportunities can be grouped by brewery department (brewing, packaging, etc.) or by low, moderate and major cost.

Low Cost: These opportunities typically have low capital cost, immediate payback, are easy to implement and are known as "low hanging fruit" in most circles.

Examples include:
- Repairing steam and air leaks
- Shutting down equipment when not used
- Shutting off lighting in areas where lighting is not required
- Changing air filters
- Replacing incandescent bulbs with CFL or LED lamps
- Repairing frail or missing insulation
- Cleaning exhaust fans and repairing or replacing loose or broken belts on fans
- Cleaning condenser coils
- Insulating refrigerant suction lines
- Checking walk-in coolers to ensure defrost timers are set properly
- Maintaining good air flow around evaporators remove debris and other objects that may block air flow
- Repairing or replacing leaky or damaged HVAC duct work

Moderate Cost: These projects tend to be a little more expensive to implement in the beginning, but still lead to cost savings in the medium turn. The range of payback period could be between 2 to 4 years.

Examples include:
- Variable speed drives (process, HVAC, and support applications)
- High-efficiency lighting systems
- Motion sensors
- New insulation
- High-efficiency HVAC units
- Automated building energy management system (EMS)
- Excess air control for boilers
- Improving condensate return
- Certain brewhouse heat recovery projects
- Purchasing ENERGY STAR equipment
- Replacing HVAC units older than 15 years with higher efficient SEER unit
- Installing programmable controllers and using set back temperature settings during hours when facility is not occupied
- Installing window blinds or shades for daytime heat reduction
- Reducing start up time for boilers, conveyors etc.
- Turning off warming cabinets when not in use

- Ensuring hot water heater set points for food prep, restroom facilities etc. are set properly

Major Cost: These opportunities require the most capital expenditure at the onset. The range of time to recoup investment could be more than 3 years.

Examples include:

- Boiler flue stack heat recovery condenser
- Brew kettle stack heat recovery
- Renewables
- New equipment (VSD air compressor, refrigeration chiller, etc.)
- Installing high-grade energy-efficient windows and doors
- Installing a "white" or "green" roof for the brewery

These cost categories will be used throughout this section to align opportunities with cost, savings and payback. Some opportunities could fall into more than one category - business objectives, capital restraints and other conditions will determine how the opportunity is categorized.

Low-cost efforts should be defined and implemented before moving on to the higher cost categories.

The following table summarizes the top ten energy savings opportunities for breweries and brewpubs/restaurants:

Top 10 Energy Best Practices; Breweries and Brewpubs/Restaurants

ITEM	TOP 10 BREWERY RELATED ENERGY BEST PRACTICES
(1)	Turn off equipment when not in use
(2)	Engage employees on how to conserve and use energy more efficiently
(3)	Replace air filters on air handlers, HVAC units etc. on regular intervals
(4)	Identify and repair compressed air, steam and water leaks
(5)	Repair or Replace damaged or missing insulation
(6)	Eliminate the use of compressed air for cleaning, cooling or other applications
(7)	Review all energy set points on a regular basis
(8)	Upgrade incandescent, T-12 Fluorescent to more efficient lighting types
(9)	Collect steam condensate
(10)	Purchase and install energy efficient equipment

Factors that may influence plant energy levels include:

- *Maintenance* - Regularly performed maintenance activities can result in improved energy efficiency within the brewery operation. Maintenance personnel should inspect for leaks, broken belts, stuck dampers, dirty filters and a host of other day-to-day operational equipment conditions. Employing efficient maintenance strategies in a timely manner will result in lower operating cost as well as lower energy usage and can be accomplished without using capital dollars.
- *Occupancy* - Is energy use consistent with occupancy? Compare usage during the week with usage at night, weekends or holidays and see if energy is being consumed outside of working hours.
- *Production levels* - Compare energy use against production levels. Increased production will usually cause increased energy use. However, this may mask the true relationship, as the lighting or cooling/heating energy use may not change much against production levels. Therefore try to separate out non-production related energy use in normalizing data.
- *Weather* - Daily or seasonal variations in the weather will influence energy use. There should be a direct relationship between weather conditions and energy use.

3.1 Brewing

The previous section provided best practice examples grouped into low, moderate and major cost initiatives. It also introduced the concept of a top ten list for energy reduction. This section focuses on additional best practices specific to brewing.

Best Practices – CO_2 Recovery Systems

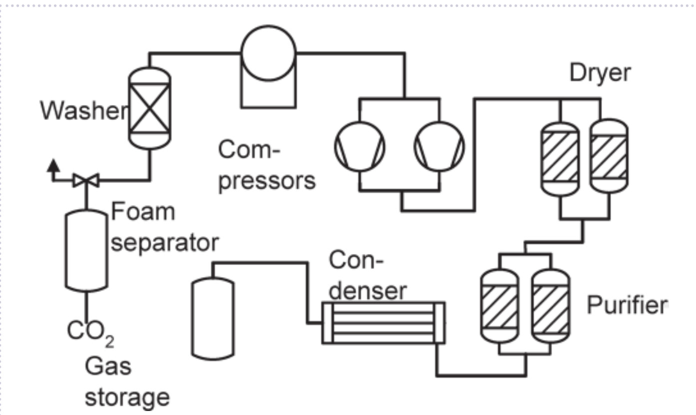
A major byproduct of the brewing process is CO_2. CO_2 is generated during the fermentation process and depending on the brewer the CO_2 will be vented or captured for reuse within the brewing system. CO_2 gas is also needed in the brewing process for bottling, flushing, carbonation, tank blankets and other uses. Capturing CO_2 and reusing the gas will lower operating cost, reduce the risk to the product and provides the opportunity to improve energy efficiency within the brewery.

There are different types of CO_2 recovery systems that are available to capture and reuse CO_2. The system incorporated will depend on the operation, the size of the brewer, the physical footprint of the brewery and the cost to purchase CO_2 within a given region.

CO_2 recovery systems can be purchased in modular skid-mounted standard design systems for smaller breweries to systems that are designed to match the process flow and equipment to the CO_2 recovery needs. These systems can range in size from 18 kg/h to 9,000 kg/h.

CO_2 recovery begins within 24 hours of fermentation; however, due to the impurities in the CO_2 gases, venting of the gas may occur until the high concentrations of nitrogen and oxygen are reduced to 99.5 or greater volume %. The gas is then collected cleaned, dried and in some cases compressed to be storage for later use. With this process the gas will then be re-vaporized when needed within the brewing process. With this process about 50% of the released CO_2 can be captured for reuse. The remaining CO_2 needed within the brewery will need to be purchased from a third party.

The Standard Method for CO_2 Recovery[1]

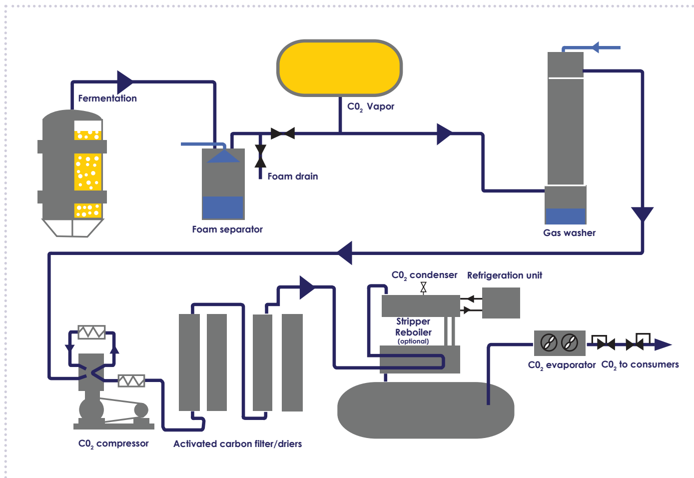


Collecting the CO_2 earlier in the fermentation process, when concentrations of nitrogen and oxygen are higher, would result in less CO_2 being released to the atmosphere and also allow for larger quantities of CO_2 to be captured for reuse within the brewing process. In some cases the amount of CO_2 recovered may exceed the needs of the brewer allowing the brewer to be self-sufficient in CO_2 production.

CO_2 recovery systems that transform CO_2 collected earlier in the fermentation process incorporates the use of a liquefaction/stripping system that allows for CO_2 to be collected at 80% to 99.5% impurities levels and be transformed to purity levels of <5ppmv O_2. Collecting CO_2 earlier will allow for larger quantities of CO_2 to be collected which results in third party purchases being reduced, lower risk to CO_2 quality impacts, and supply.

The diagram below shows the traditional CO_2 collection methods and the installation of CO_2 stripper/reboiler that allows for less pure CO_2 to be collected and purified meeting brewing quality requirements. Please note that many manufactures provide solutions with this technology. This system can be provided for CO_2 collection for small-volume and large-volume breweries.

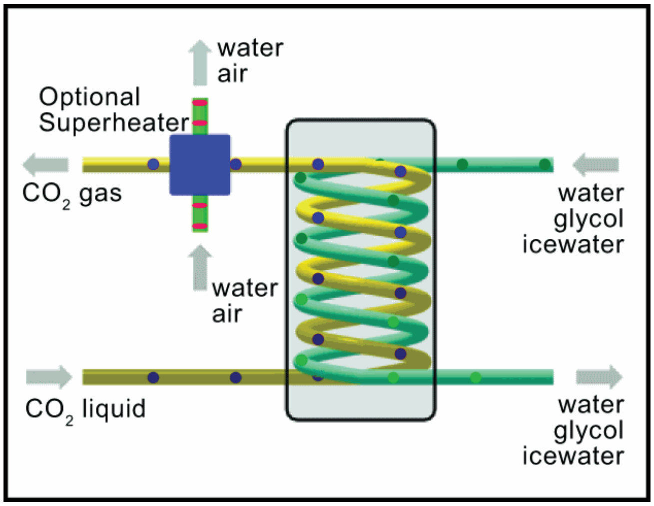
Traditional CO_2 Collection Methods and the Installation of CO_2 Stripper/Reboiler[2]



Energy efficiency can be achieved within the CO_2 recovery system as well. If CO_2 is collected and stored as a liquid under pressure for future use it must be vaporized from a liquid to a gas for use in the brewing process. The vaporization process requires heat to change the state of the CO_2. In some cases this vaporization process uses steam, hot water or electric heaters to convert the liquid to gas.

However, there is an opportunity to convert the cold energy stored in the CO_2 to secondary refrigeration system. Installing a heat exchanger with cold CO_2 liquid on one side.

CO_2 Cold Energy Conversion[3]



and warm glycol or water returning from the process to the refrigeration chillers can be used to vaporize the CO_2 and the heat extracted from the warm stream will help lower energy usage as well. This heat recovery process will help lower energy usage and cost associated with the steam, hot water or electricity used to vaporize CO_2.

Advantages of CO_2 Recovery

- Lower operating cost (limit third-party purchase)
- Lower environmental impact (less CO_2 vented) Reduce risk to beer quality (use brewery-produced CO_2)
- Reduce risk to supply (changes in CO_2 suppliers)

Barriers to CO_2 Recovery

- Low cost and ample supply of third party CO_2
- Low volume of CO_2 generation
- Limited footprint to install CO2 recovery system
- Capital restraints or low ROI for collecting CO2

Factors to Consider When Investigating CO_2 Recovery

- Amount of CO_2 vented on an annual basis
- Amount of CO_2 purchased
- Cost of CO_2 purchased
- CO_2 supplier network (stability, quality, availability etc.)
- Available footprint for CO_2 recovery equipment
- Capital cost for CO_2 recovery system
- Type of system required
- Partial collection that collects CO_2 at high purity levels (may need to purchase additional CO_2)
- Complete system that includes stripper/reboiler allowing for earlier collection of CO_2 (may allow brewer to be CO_2 self-sufficient)

3.2 Packaging

Best Practices - Variable Speed Drives

A variable speed drive (VSD) works by converting the incoming electrical supply of fixed frequency into a variable frequency output. This variation in frequency allows the drive to control how the motor operates — a low frequency for a slow speed and a higher frequency for a faster speed. The output can also be changed which enables the motor to generate more or less torque as needed. The motor and drive combination can therefore be used for turning a large load at fairly slow speeds, or turning a lighter load at high speeds, thus maximizing efficiency.

VSDs are supplied in a wide range of sizes (from 0.18 kW to several MW) and may be optimized to suit particular applications. Though not all applications benefit from variable control, the main benefits are:

- Improved process control resulting in output product quality
- Programmable soft starting, soft stopping and dynamic braking, which reduce excessive stress placed on the motor and extend its life
- Wide range of speed, torque and power output giving a greater degree of control (For example, the electronically controlled VSD has the ability to set various parameters such as allowing differing acceleration rates for different speed changes or having the ability to increase/decrease the torque output at different speeds.
- Improved efficiency through an increase in the power factor of the system - this means that more of the current drawn is actually used to drive the load, making it more efficient.
- Dynamic response comparable to DC drives leading to better control
- Energy savings in many applications - there are a number of applications where it is possible to reduce the speed of a motor while keeping the same outcome (such as in ventilation systems designed to satisfy a building's maximum occupancy). In most cases, installing an electronic VSD is the most efficient method of doing this.

When applied properly, variable frequency drives (VFDs) or VSDs are very effective motor controllers in bottling operations. Modern VSDs are affordable and reliable, have flexibility of control, and offer significant electrical energy savings (savings from 10 – 60%) through greatly reduced electric bills.

VSDs and VFDs are used in a wide variety of applications for various reasons, such as in pump and fan applications where they are the most effective energy savers.

To obtain a clear understanding of the proper and most effective application of VSDs, it is essential to gain a working knowledge of VSD basic theory as well as a strong familiarity with practices.

VSD[4]

Applying a VSD to a specific application is much easier if the requirements of the load are understood. Simply put, the VSD must have ample capability for the motor so that the motor can produce the required torque for the load. Remember that machine torque is independent of motor speed and that load horsepower increases linearly with rpm.

Know your load torque requirements. Every load has distinct torque requirements that vary with the load's operation; the motor via the VSD must supply these requirements. It is important to have a clear understanding of the torque load for each application in which a VSD is being considered. Data can be retrieved from the pump or fan vendor.

The speed of an induction motor is proportional to the frequency of the AC voltage applied to it, as well as the number of poles in the motor stator. This is expressed by the equation:

RPM = (f x 120) / p, where f is the frequency in Hz and p is the number of poles in any multiple of 2

Therefore, if the frequency applied to the motor is changed, the motor speed changes in direct proportion to the frequency change. The VSD controls the frequency applied to the motor.

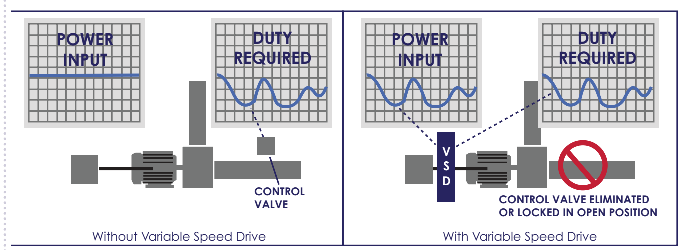
VSD's primarily operate to convert electrical system frequency and voltage to the required levels to drive a motor at a speed other than its rated speed. The two most basic functions are to provide power conversion from one frequency to another and to enable control of the output frequency.

Consequently, a 20% reduction of the rotational speed leads to a 49% reduction in power requirement. These relationships and resulting energy savings achieved by VSDs are due to the pressure difference across the impeller or valve. When less pressure is produced, less acceleration of air or fluid across the impeller is required. It is the simultaneous reduction of acceleration and pressure that multiplies the savings.

It is important to note that a VSD does not constrain the rotational speed of a motor to a certain level in order to achieve energy savings. This would mean that the power input would at times be insufficient. The main advantage of a VSD is that it can alter the rotational speed of a motor so that the power input can match the duty required and diminish energy wasting.

When the system operates without the use of a VSD, the power input remains constant regardless of changes in the load output over time, because the controlling device is a throttle or damper. When a VSD is used, the input power is tailored to suit the output duty. The throttle or damper is eliminated with savings in maintenance.

Operation of a System With and Without VSD



Although dampers are often used to regulate the output of fans, reducing the speed is a much more efficient way to achieve the same effect. With damper control, the input power reduces as the flow rate decreases. However, under VSD control, the variable torque characteristics of the fan means that the relationship between flow and speed of the fan is such that the input power reduces in a cube law relationship with the speed reduction. This is shown in the graph, where the energy expended using a VSD is significantly less than the damper-controlled motors. It also shows the limitations of a VSD that it is normally not able to reduce the flow all the way to zero.

In a similar way to using damper control in fan applications, using throttle control for pumping applications results in a poor efficiency as the pump is not being run at its design point. This is particularly true for applications with a steep flow/head characteristic, where there is a high static head such as in heating circuits and for small pumps.

Using a VSD to control the pump instead of simple throttle control can result in significant power and cost savings. Note that on systems with a high static head (for example, boiler feed water pumps), where the pump must overcome the inherent resistance of the system before any flow starts, the benefits of using VSDs will be slightly reduced. This is because the additional resistance affects the relationship between the speed of the pump and the flow. Factor this into any calculations and consult an equipment supplier for further information if needed.

Make an overview of all motors in the plant using the following format. Check the following motors specifically:

- Water pumps that currently use a control valve to vary flow or pressure.
- Conveyer systems that do not have a control of varying line speeds.
- All pumping systems that control on pressure or flow (boiler pumps, bottle washer pumps, CIP pumps, etc.)
- Fans that control air flow, like HVAC, boiler fans, etc.
- Compressors (Chillers, compressed air)

Data Collection and Documentation of Pumping Equipment

Location	Motor ID	Motor application	Installed power (hp or kW)	Variable torque / demand (Y/N)	Annual operating hours

Define the operating profile of the load to which the VSD is to be applied. Include any or all of the "torques" discussed above. Using a recorder (A, V, kW) to record the motor's current draw under all operating conditions will help in doing this. Obtain the highest "peak" current readings under the worst conditions. Also, see if the motor has been working in an overloaded condition by checking the motor full-load amps (FLA). An overloaded motor operating at reduced speeds may not survive the increased temperatures as a result of the reduced cooling effects of the motor at these lower speeds.

Determine why the load operation needs to be changed. Very often VSDs have been applied to applications where all that was required was a "soft start" reduced-voltage controller. The need for the VSD should be based on the ability to change the load's speed as required. In those applications where only one speed change is required, a VSD may not be necessary or practical.

Evaluate the possible application of a VSD on the motors from the survey. If you answer any of the following questions with YES, be extra careful in your VSD selection and setup parameters of the VSD.

Will the VSD operate more than one motor? The total peak currents of all motor loads under worst operating conditions must be calculated. The VSD must be sized based on this maximum current requirement.

Will the load be spinning or coasting when the VSD is started? This is very often the case with fan applications. When a VSD is first started, it begins to operate at a low frequency and voltage and gradually ramps up to a preset speed. If the load is already in motion, it will be out of sync with the VSD. The VSD will attempt to pull the motor down to the lower frequency, which may require high current levels, usually causing an overcurrent trip. Because of this, VSD manufacturers offer drives with an option for synchronization with a spinning load; this VSD ramps at a different frequency.

Will the power supply source be switched while the VSD is running? This occurs in many buildings, such as hospitals, where loads are switched to standby generators in the event of a power outage. Some drives will ride through a brief power outage while others may not. If your application is of this type, it must be reviewed with the drive manufacturer for a final determination of drive capability.

Is the load considered hard to start? These are the motors that dim the lights in the building when you hit the start button. Remember, the VSD is limited in the amount of overcurrent it can produce for a given period of time. These applications may require oversizing of the VSD for higher current demands.

Are starting or stopping times critical? Some applications may require quick starting or emergency stopping of the load. In either case, high currents will be required of the drive. Again, oversizing of the VSD may be required.

Are external motor disconnects required between the motor and the VSD? Service disconnects at motor loads are very often used for maintenance purposes. Normally, removing a load from a VSD while operating does not pose a problem for the VSD. On the other hand, introducing a load to a VSD by closing a motor disconnect while the VSD is operational can be fatal to the VSD.

Are there power factor correction capacitors being switched or existing on the intended motor loads? Switching of power factor capacitors usually generates power disturbances in the distribution system. Many VSDs can and will be affected by this. Isolation transformers or line reactors may be required for these applications.

While there are many specifications associated with drives, the following are the most important:

- Continuous run current rating. This is the maximum rms current the VSD can safely handle under all operating conditions at a fixed ambient temperature (usually 40 °C (104 F).
- Overload current rating. This is an inverse time/current rating that is the maximum current the VSD can produce for a given time frame. Typical ratings are 110% to 150% overcurrent for 1 min, depending on the manufacturer. Higher current ratings can be obtained by oversizing the VSD. This rating is very important when sizing the VSD for the currents needed by the motor for breakaway torque.
- Line voltage. As with any motor controller, an operating voltage must be specified. VSDs are designed to operate at some nominal voltage such as 240VAC or 480VAC, with an allowable voltage variation of plus or minus 10%. Most motor starters will operate beyond this 10% variation, but VSDs will not and will go into a protective trip. A recorded voltage reading of line power deviations is highly recommended for each application.

Energy savings depend on operating hours of the motors. A safe way of calculating the potential savings is using a 25% saving potential on the current energy use of your motor (current energy use = kW*operating hours).

A certified electrical engineer or VSD, pump or fan vendor must install the VSD. The supplier will also provide instructions on how to install the VSD and set the right parameter settings.

The brewery needs to make sure that the VSD and the motor that the VSD will control are a match. New installations should have inverter duty rated motors, installed with the VSD to accommodate the necessary cooling for the different speeds. If the VSD is installed with an existing motor that is not inverter duty rated the motor life may be shorten due to overheating. It is not required to change the motor but the reader needs to be aware that this condition may exist and the motor may have a shorter life cycle.

3.3 Support Systems (Utilities)

Best Practice - Lighting

There are many low-cost and no-cost measures that can be utilized to help reduce energy costs, without adversely affecting working conditions. In most cases upgrading the existing lighting system will save 30% to 40% of the current electrical energy consumed for lighting systems in an average-sized plant. Choosing a sustainable lighting solution is an excellent way to reduce energy consumption and overall operational costs. Likewise, sustainable lighting solutions can provide better, task-appropriate lighting that can increase productivity, reduce errors, and improve employee well-being throughout a facility.

This section provides background knowledge and some practical tips on using lighting as cost effectively as possible. Through strategic planning and performance management of the overall lighting system, costs can be reduced and lighting quality improved. The objective of this guideline is to show how lighting systems impact your energy consumption and help with maintenance and design tips on how to reduce the lighting costs across your facility.

Daylighting

Daylight is an acceptable and desirable light source for building interiors. It uses the light from the sky, or occasionally sunlight reflected off building surfaces. Since daylighting components are normally integrated with the original building design, it may not be possible to consider them for a retrofit project. Light is a key factor (rivaled only by air quality) in a healthy and productive work environment. Therefore, daylighting technologies may provide opportunities to offer the wellness benefits of natural light to workers. The guideline will focus on electric powered lights given that bottling and office facilities employ this type of system as their primary source of light. There are many types of lamps, ballast and lighting systems used around the world in many different industries this guideline describes lighting sources found at many bottling operations worldwide and will be updated on a regular basis to include new systems as they are introduced.

Electric Lamps

The lamp is the source of electric light, the device that converts electric power into visible light. All lighting systems, no matter how complex, have basic performance principles which include the following:

- Lumen output – the amount of light emitted by a lamp

- Efficacy – the efficiency of lamps, measured in lumens of light per watt of energy.
- Rated lamp life – expected lamp life typically reported in hours.
- Lamp lumen depreciation – the loss of light output over time, usually reported as a percentage.
- Color temperature (CT) and color rendering (CRI) – a numerical value related to light appearance.
- Luminaire – a light fitting that incorporates the lamp.
- Controls – manual or automatic switching equipment, which operates the lighting system

A part of a lighting maintenance plan is to first, identify your lamp types. In manufacturing and industrial facilities lamps that are primarily utilized are fluorescent, high intensity discharges (HID), incandescent/halogen lamps and light emitting diodes (LEDs). The first step in planning a lighting maintenance strategy is to define the existing condition of the lighting systems.

Fluorescent lamps are typically used in offices and commercial buildings and most low bay industrial applications:

- T12 lamps – Linear fluorescent lamps that are now considered obsolete. These were the standard fluorescent lamps until T8 lamps came on the market over 20 years ago.
- T8 lamps - These lamps became popular in the industrial/commercial lighting industry and have become the standard for offices and general applications. Since they are 22% more efficient than T12s, it is generally always cost-effective to retrofit or replace fixtures that use T12 lamps in existing applications. T8 lamps use the same socket as T12, but not the same ballast.
- T5 lamps - These cannot replace T8 lamps because they have different characteristics and different lengths, socket configurations and ballasts. T5s are smaller lamps than T8s, but have similar efficacy (lumens per watt).
- Compact Fluorescent Lamps (CFLs) - Fluorescent lamps with a single base and bent-tube construction. The first CFLs had a screw-type base. While screw base lamps are still available, commercial applications typically use lamps with a 4-pin base.

Other lighting options include:

- High Intensity Discharge (HID) - Lamps use a gas-filled tube to generate light, but use arc current and vaporized metals at relatively high temperatures and pressures. There are two main types in current use – metal halide (MH) and high-pressure sodium (HPS). Both can be used for industrial lighting including high bay applications (indoor spaces with high ceilings), flood lighting and street lighting.
- Incandescent/Halogen lamps - A halogen lamp is a form of incandescent lamp that introduces traces of halogen gas and a quartz envelope to burn hotter and prolongs the filament life. Halogen should be used in lieu of standard incandescent. Whenever possible, the use of more efficient CFL or ceramic metal halide sources should be explored. Incandescent/halogen lamp types are very inefficient (roughly five times less efficient than fluorescent); these lamps should not be used at a minimum.
- Light Emitting Diodes (LEDs) - Lamps are made of an advanced semi-conductor material that emits visible light when current passes through it. LEDs are beginning to see extensive use in a variety of applications including parking lot lighting and refrigerated display case lighting. One major disadvantage of LEDs is that these lamps are currently more expensive, price per lumen, on an initial capital cost basis, than more conventional lighting technologies. Also LEDs emit a more tightly focused beam that may prove to be too bright.

Fluorescent and high intensity discharge (HID) lamps require ballasts (incandescent lamps do not). Ballasts typically are designed to efficiently operate a specific lamp type, so lamps and ballasts are chosen together. Electronic ballast and magnetic ballast are the two main types of ballasts used today. Since magnetic ballasts are not as sophisticated as electronic ballasts and can be problematic, they are being replaced by the electronic versions. Electronic ballasts are energy efficient and therefore lower your monthly energy bill. T8 lamps using electronic ballasts are more efficient than using T12 lamps with magnetic ballasts.

Lighting requirements will vary at different times and in different parts of a building throughout the day. Ensure that lighting controls are set to match demand, that is, when required during business hours.

A comprehensive strategy may use manual or automatic control devices in concert, responding to plant specific usage patterns. However, automatic controls allows for greater savings in cost and usage.

Today most lighting controls are focused on fluorescent lamps and fixtures due to their ability to function in a rapid start mode. The inclusion of motion sensors in areas where traffic is infrequent or limited may increase the energy savings attributed to the lighting upgrade by an additional 5 to 10%.

Automatic controls provide benefits in user comfort and energy conservation. Automatic controls can deliver reliable energy savings without personnel or employee participation.

The following are examples of automatic controls:

- Occupancy sensors turn off the lights when they detect that no occupants are present. The occupancy sensor includes a motion sensor, a control unit, and a relay for switching the lights. Ultrasonic and Passive Infrared sensor technology are utilized in detecting motion and heat of occupants. They can be used together in a dual-technology fashion. High quality occupancy sensors use the dual technology, since it is more reliable than each of the separate technologies used independently.
- Switching, dimming, or a combination of the two functions can be automatically preprogrammed so that the user can select an appropriate lighting environment. A pre-set can be included for the cleaning crew, which then can use the most energy-efficient lights that will allow them to do their work.
- Time clocks are devices that can be programmed to turn lights on or off at designated times. These are a useful alternative to photoelectric sensors in applications with very predictable usage, such as in parking lots.
- Daylight controls are photoelectric devices that turn off or dim the lights in response to the natural illumination available.

Key Lighting Strategies

- Upgrade incandescent and fluorescent T12s to high-lumen T8s, T5s or T5Hos Example: a standard 40 watt T12 lamp on standard magnetic ballast uses 172 watts of energy. The same fixture retrofitted with T8 lamps and electronic ballast uses 112 watts of energy – that's a 35% reduction in energy usage.
- Replace magnetic ballasts with energy-efficient electronic ballasts
- Ballasts and lamps should be replaced at the same time. Consider rapid start and dimmable ballasts to coordinate with an energy management system
- Replace High-Intensity Discharge (HIDs) systems with fluorescent T8s and T5s or T5Hos -6-lamp T5 and T8 fixtures are becoming very popular for industrial use.
- De-lamp unneeded fixtures (remove lamps). Fluorescent Fixtures can be de-lamped to save the energy consumption in the area which the luminance level is higher than what is necessary. Convert multi-lamp T12 fluorescent fixtures to T8 fluorescent fixtures with fewer lamps per fixture.
- Remove fluorescent lamps controlled by magnetic ballasts in pairs since they are operated and wired in pairs (two fluorescent lamps from a four-lamp fixture). With electronic ballasts, each lamp can be controlled individually.
- If the ballast operates in parallel, lamps can be removed without removing all the lamps.
- Use compact fluorescent lighting (CFLs) in place of incandescent lamps.
- Consider connecting outdoor and indoor lighting to an energy management system if not already, for indoor and outdoor lighting.

Maintenance Planning

A pro-active maintenance plan should be used to maintain the lighting system at most energy efficient level possible. Many facility managers are hesitant to replace lamps that are still operating. But group re-lamping and cleaning can be less expensive than spot replacement. Through strategic planning and performance management of the overall lighting system, costs can be reduced and lighting quality improved. Examples include:

- Cleaning of lamps and luminaires at regular intervals.
- Never clean lamps that are operational or still hot. Use very mild soaps and cleaners, followed by a clean rinse on most surfaces. This can be done on a yearly basis.
- Group re-lamping on a scheduled basis of all luminaires in an area.
- One simple method of determining when to re-lamp: When group re-lamping, one may buy 10% more lamps than are needed to re-lamp the area. The use of this 10% overstock is limited to spot re-lamping only. When you have depleted the 10%, this indicates that it is time to group re-lamp again. This method typically results in group re-lamping at about 70% rated lamp life.
- Inspection and repair of lighting equipment at regular intervals. Any repairs should be completed by an experienced or licensed electrician.
- Yearly have ballasts and lighting controls be factory pre-set to the greatest extent possible by a lighting contractor.

Best Practice - Compressed Air

Compressed air services many purposes in breweries. It helps position kegs, bottles and cans for filling, moves spent grain, is necessary for control valves to operate, and is used to push liquid from vessels when pumping is not available. In some cases it is used to operate agitators and hand tools and as packaging equipment.

Compressed air is considered to be a free source of energy by many employees, but is actually one of the most expensive utilities within a brewery. At its best, the system is 12 to 15% efficient. This means that for every kW of energy used to produce compressed air, only 12-15% is delivered to the source. The remainder of the energy is lost in the form of heat. Therefore it is imperative to reduce compressed air usage whenever possible. Set compressor air pressure to the lowest possible level, and above all find and fix air leaks on a continuous basis.

The following items provide a quick reference on simple ways to improve energy efficiency within the compressed air system:

- Set air pressure at the lowest possible level to maintain operations (rule of thumb lowering header pressure by 2 PSI will improve air compressor energy efficiency by 1%)
- Replace compressed air knives (nozzles) used to blow off water on cans or bottles with low pressure fan blowers
- Do not use air for cleaning equipment or floors where dry clean up would be more appropriate
- Do not use air tools or compressed air for personnel cooling
- Avoid using air to power motors if possible
- Exhaust hot air out of compressor room and bring in cool outside air whenever possible (rule of thumb dropping the suction temperature by 10F will improve compressor energy efficiency by approximately 2%. (Note: Check with compressor manufacture to determine what lowest suction temperature at which the compressor can operate without damaging the compressor)
- Repair air leaks as soon as possible.

Compressed air leaks are very common. Leaks are a major source of inefficiency and in some cases will account for 30% - 40% of compressed air system. Leaks also increase the system pressure drop, requiring additional compressors to be put on line or operating the single compressor at full load to maintain system pressure. This higher pressure takes more energy to produce, shortens the life span of equipment, and causes equipment that need compressed air to operate less efficiently.

Although all possible measures should be taken to limit compressed air leaks, it is nearly impossible to operate with zero air leaks. In general, if air leaks are limited to 5% or 10% of the compressed air produced, then the system will operate efficiently.

Compressed air leaks cost money! Below are a few examples of the cost savings that can be incurred when air leakage is reduced.

Cost of Compressed Air Leaks

Leak Diameter	Air loss cfm	Energy loss (kWh)	Costs (Us$)/YR
inch	85 PSI	85 PSI	85 PSI
1/16	2	0.4	320
1/8	20	3.7	2,960
1/4	55	10.3	8,240
3/8	221	41.4	33.120

(*) kW x $0.1/kWh x 8,000 annual operating hours

Fixing compressed air leaks provides the highest payback in the shortest period of time.

Air leaks occur all the time - though some are easy to identify while others can be difficult. The best time to identify air leaks is when the equipment is shut down; however, this will only allow a certain amount of leaks to be identified. Others will need to be located when the equipment is running.

A system drawing outlining the compressed air system components will help employees identify where the leaks are located. The drawing should show the major pieces of the equipment, piping layout, possible areas that have the highest potential for air leaks, and track where leaks have occurred.

Compressed Air System Components[5]

Providing pictures, posters and training on what equipment requires compressed air will also help identify air leaks. This is a simple way to engage employees in energy reduction efforts. The following charts show a few examples of where air leaks may occur.

Common Leak Locations

Cost profile for different methods and practices to identify and repair air leaks:

- Identify and stop at once ($)
- Use the look and listen method after normal working hours ($)
- Invest in an ultrasound listening device to identify leaks ($)
- Consider purchasing a compressed air leak tester to detect pressure drops due to leaks and measure the unit capacity ($$)
- Consider implementing an automatic leak-measuring process to be conducted on weekends through a computerized control, regulation and monitoring system and installation of enough section valves ($$)

The following KPI parameters should be used for compressed air systems:

- Plant air flow during normal operations
- Plant air flow during down time
- Plant air pressure during normal and down time operation

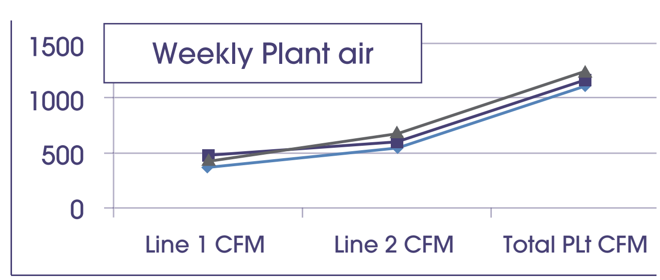
To ensure continuous lowering of compressed air usage, the following benchmark parameters should be used:

- Compare normal air flow totals on a weekly basis
- Compare normal air flow totals to down time totals on a weekly basis
- Develop trends and checkpoints to determine normal range
- Assign individuals to act immediately on deviations and ensure that root cause for excursion is identified and acted upon
- Document reasons for excursions and methods executed to improve the operation - this information should be documented and archived to allow for future problem solving

Action items to be taken by the brewery team include:

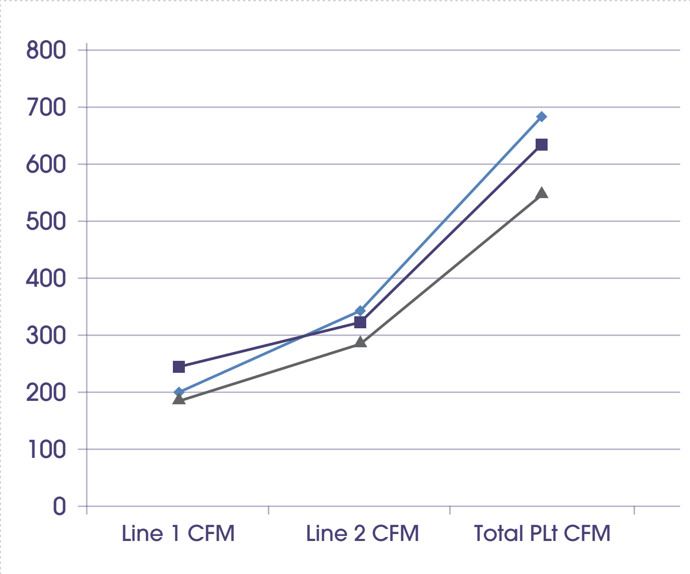
- Collecting plant air pressure and air flow data on a daily basis. Enter the plant pressure and flow into a book or spreadsheet. The air pressure and air flow should be measured once per shift at the same time every day. If the air pressure and air flow data is available electronically, set up trends to monitor the air pressure on a continuous basis. Identify air pressure and air flow measurements during both normal operations and when the production is shutdown.
- Totalize air flow on a weekly basis and create a trend that shows weekly air flow totals. Totalize plant air flows for each shift, daily and weekly. Any changes in air flow from week to week should be investigated and what caused the change should be determined.

Compressed Air Leak Tracking



The plant airflow should also be tracked when the line is shut down and when the plant is shut down. When compared from week to week, an increase in air flow during shutdown may indicate the presence of new leaks, or that some equipment may have been left on. A decrease in air flow may indicate that air leaks have been reduced. Benchmarking this data weekly will help identify leaks and confirm that air leaks are being repaired in a timely manner.

Compressed Air Leak Tracking



Week to week benchmarking will begin to develop trends that will help identify wasted air through leaks or operational issues. Benchmarking will also verify that air leaks are being reduced and compressed air usage optimized

Best Practices – Boiler Efficiency

Today, in the brewing industry, process and heating applications continue to be powered by steam and hot water. The mainstay technology for generating heating or process energy is the traditional boiler. Whether firetube or the various watertube forms, the commercial or package boiler has proven to be highly efficient and cost effective in generating energy for many process and heating applications.

In order to maintain the highest possible boiler efficiency, the boiler system should be tuned on a regular basis by a boiler control professional. It is recommended that this practice take place at a minimum of every three years. Best practice would be to tune the boiler yearly during the annually scheduled boiler maintenance period. This guideline describes the parameters used to determine the optimal boiler efficiency and should be incorporated into normal operational activity.

While good maintenance is the first essential step in achieving high boiler efficiency, managers have a number of options that can further improve boiler efficiency. Some can be applied to existing boiler installations, and others are only suitable when replacing boilers.

To get the most out of the boiler system it is necessary to implement a complete maintenance/efficiency plan to maintain every aspect of efficiency. Providing that a maintenance/efficiency plan is put into place and plant personnel can perform the tuning with the appropriate tools a cost savings in energy use can be realized.

As discussed before, boilers are pressure vessels designed to heat water or produce steam, which can then be used to provide space heating, process heating and water heating to a facility. The heating source in the boiler can be a natural gas fired burner or oil fired burner and electric resistance heater can be used as well.

Basically, boiler efficiency represents the difference between energy input and energy output. Boiler efficiency describes the fraction of fuel energy that is converted into useful steam energy. In the end, efficiency comes down to properly evaluating the performance of the boiler and the performance of the burner.

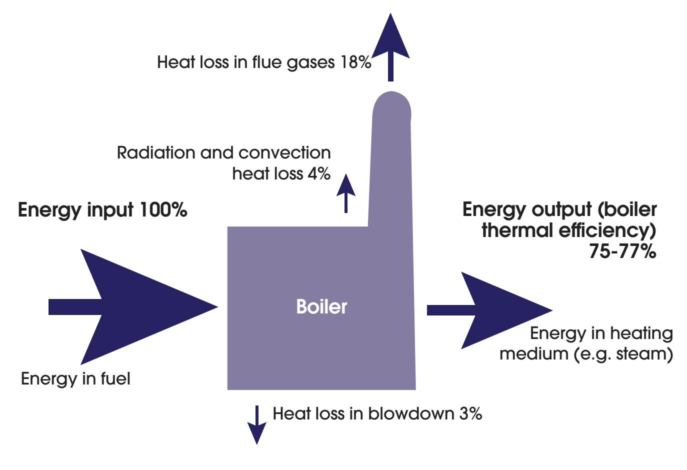
There are three terms that influence boiler efficiency; combustion efficiency, fuel-to-steam efficiency and thermal efficiency. They are defined as follows:

- *Combustion Efficiency* - Combustion efficiency is an indication of the burner's ability to burn fuel and the ability of the boiler to absorb the heat generated. The amount of unburned fuel and excess air in the exhaust gas are used to assess a burner's combustion efficiency. Burners performing with extremely low levels of unburned fuel while operating at low excess air levels are considered efficient. In other words, combustion efficiency is measured by dividing the usable heat produced by the fuel input in MJ/h content. This calculation is based on the actual heat available produced by the system after heat loss up the stack and other heat losses which do not provide usable heat.
- *Fuel-To-Steam Efficiency* - Fuel-to-steam efficiency is a measure of the overall efficiency of the boiler. It accounts for the effectiveness of the heat exchanger as well as the radiation and convection losses.
- *Thermal Efficiency* – Thermal efficiency of a boiler is defined as the percentage of (heat) energy input that is effectively useful in the generated steam. It is related to how efficient the heat exchanger is working. Certain conditions such as soot build-up

or water scaling can reduce the overall efficiency of the boiler system resulting in additional operating cost due to higher fuel usage to produce steam.

As briefly mentioned before, heat losses do occur. These losses can be looked at as avoidable and unavoidable energy losses.

Heat Losses[6]



A heat balance will help to identify avoidable and unavoidable heat losses. A heat balance is an attempt to balance the total energy entering a boiler against that leaving the boiler in different forms. Conducting boiler efficiency tests help find out the deviation of boiler efficiency from the best efficiency and target problem areas for corrective action.

The goal is to minimize or reduce the avoidable losses and thereby improve energy efficiency. The following losses can be avoided or reduced:

- *Stack gas losses* - Stack temperature is a measure of the heat carried away by dry flue gases and the moisture loss. The stack temperature is the temperature of the combustion gases dry and water vapor leaving the boiler and reflects the energy that did not transfer from the fuel to the steam or hot water. The lower the stack temperature is, the more effective the heat exchanger design and the higher the fuel-to-steam. Stack gas temperature can be reduced by optimizing maintenance and cleaning, better burner and boiler technology.
- *Excess air* - It uses energy from combustion which takes away potential energy for transfer to water in the boiler. In this way, excess air reduces boiler efficiency. Minimize air to the necessary minimum which depends on burner technology, operation and maintenance.
- *Blow-down losses* - The boiler water must be sufficiently free of deposit forming solids to allow rapid and efficient heat transfer and it must not be corrosive to the boiler metal. Deposits and corrosion result in efficiency losses and may result in boiler tube failures and inability to produce steam.
- *Condensate losses* - Recover the largest possible amount of condensate. Hot condensate that is not returned to the boiler represents a corresponding loss of energy. The energy savings is the energy contained in the condensate being returned.
- *Convection and radiation losses* - Radiation and convection losses represent the heat losses radiating from the boiler vessel. Boilers are insulated to minimize these losses. Radiation and convection losses, are essentially constant throughout the firing range of a particular boiler, but vary between different boiler types, sizes, and operating pressures. Having proper insulation of the boiler is a good solution to this issue.

Two methods for measuring boiler efficiency include the Direct Method Procedure, and the Heat Loss Method. Both methods will assist the plant in calculating boiler efficiency the method chosen will depend on the available data for each procedure. If the data is not available for the Heat Loss Method the Direct Method measured consistently will provide a KPI for boiler efficiency that can be benchmarked over time to optimize steam generation.

Direct Method Procedure:

- Measure steam flow over a set period, e.g. one hour. Use steam integrator readings, if available, and correct for calibration pressure. Alternatively, use the feedwater integrator, if available, which will in most cases not require a correction for pressure.
- Measure the flow of fuel over the same period. Use the gas or oil integrator, or determine the mass of solid fuel used.
- Convert steam flow, feedwater flow and fuel flow to identical energy units, e.g. Btu/kg or kJ/kg.
- Calculate the efficiency using the following equation: Efficiency = 100 x (steam energy – feedwater energy) ÷ fuel energy

Heat Loss Method:

The Heat Balance efficiency measurement method is based on accounting for all the heat losses of the boiler. The actual measurement method consists of subtracting from 100 % the total percentage of: A) stack, B) radiation, and C) convection losses. The resulting value is the boiler's fuel-to-steam efficiency. The heat loss method accounts for stack, radiation and convection losses.

Efficiency of boiler (n) = 100 - (i + ii + iii + iv + v + vi + vii)

Whereby the principle losses that occur in a boiler are loss of heat due to:

i. Dry flue gas
ii. Evaporation of water formed due to H2 in fuel
iii. Evaporation of moisture in fuel
iv. Moisture present in combustion air
v. Un-burnt fuel in fly ash
vi. Un-burnt fuel in bottom ash
vii. Radiation and other unaccounted losses

NOTE: The following items are intended to assist with improving boiler efficiency. All facilities must be aware of any codes, regulations and insurance requirements that are required in order to safely operate a boiler at a given location.

These measures, taken together and combined with a comprehensive maintenance program, can result in significant energy savings. Equally important, unexpected downtime due to breakdowns will be reduced, and the overall safety of the installation will improve. The following steps can be taken to ensure peak boiler efficiency and minimum excess air operation:

- Check the calibration of the combustion gas analyzer frequently and check the zero point daily. The control may be manually altered to reduce excess air, without shortcutting the safety of operation.
- The physical condition of the forced-draft damper should be checked to ensure it is not broken or damaged.
- Casing leakage must be detected and stopped.
- Check the burner flame configuration during each shift and note any changes.
- Stack temperature should be as low as possible. However, it should not be so low that water vapor in the exhaust condenses on the stack walls.

For proper boiler operation that can lead to greater efficiency, the following measures can be applied:

- Boiler Blow-down, Heat Recover and Control
- Proper Excess Air
- Reduce Scaling and Soot Losses
- Radiation and Convection Heat Loss Minimization
- Reduction of Boiler Steam Pressure
- Variable Speed Control

Boiler Blow-down: When water is boiled and steam is generated, any dissolved solids contained in the water remain in the boiler. The deposits can lead to scale formation inside the boiler, resulting in localized overheating and finally causing boiler tube failure. It is therefore necessary to control the level of concentration of the solids in suspension and dissolved in the boiled water. This is achieved by process of 'blowing down', where a certain volume of water is blown off and is automatically replaced by feed water – thus maintaining the optimum level of total dissolved solids in the boiler water. In general boiler water (make up water) will be treated with chemicals and dissolved solids to ensure higher efficiencies and reduce the scaling. **Never use untreated RO water as boiler make up water.**

A recommended method of removing these solids is via short, sharp blasts using a relatively large valve at the bottom of the boiler. The objective is to allow the sludge time to redistribute itself so that more can be removed on the next blow-down.

It is recommended that: A single four-second blow-down every eight hours is much more effective than one, twelve-second blow-down in the first eight hour shift period, and then nothing for the rest of the day.

Significant energy savings can be accomplished by recovering heat from boiler blow-down. For example, an efficiency improvement of over 2 percent can be achieved at a 10 percent blow-down rate on a 150 psig boiler.

Blow-down of boilers to reduce the sludge and solid content allows heat to go down the drain. Installing a heat exchanger in the blow-down line allows this waste heat to be used in preheating makeup and feed water. This provides a great opportunity in energy and cost savings.

Uncontrolled continuous blow-down is very wasteful. For example, a 10% blow-down in a 15 kg/cm^2 boiler results in 3% efficiency loss. Automatic blow-down controls can be installed that sense and respond to boiler water conductivity and pH, thereby increasing boiler efficiency.

Proper Excess Air: Oxygen trim controls can be added to the burner-control system. These controls continuously monitor the oxygen level in the boiler-flue gases and adjust the quantity of air delivered to the burner, minimizing the excess air delivered. In conventional control systems, excess air levels typically are 10-20 percent. With oxygen trim controls, excess air levels can be reduced to 5 percent or less.

An electronic sensor is inserted into the boiler flue, near the boiler, ahead of any dampers or other sources of air leakage into the boiler or flue. The sensor is connected to a control panel that measures oxygen and sends a signal to a control damper on the burner air supply.

Reduce Scaling and Soot Losses: In oil and coal-fired boilers, soot buildup on tubes acts as an insulator against heat transfer. Any such deposits should be removed on a regular basis. An estimated 1% efficiency loss occurs with every 22°C or 72°F increase in stack temperature. Stack temperature should be checked and recorded regularly as an indicator of soot deposits. An upward trend in flue gas temperatures over weeks or months usually indicates that a deposit has built up on either the fireside or waterside of boiler heat-exchange surfaces. The boiler should be inspected promptly.

When the flue gas temperature rises to about 20 °C above the temperature of a newly cleaned boiler, soot deposits should be removed. A dial type thermometer can be installed at the base of the stack to monitor the exhaust flue gas temperature.

Radiation and Convection Heat Loss Minimization: The external surfaces of a shell boiler are hotter than the surroundings. The heat loss from the boiler shell is normally a fixed energy loss, regardless of the boiler output. It is recommended that repairing or augmenting insulation can reduce heat loss through boiler walls and piping.

Reduction of Boiler Steam Pressure: This is an effective means of reducing fuel consumption by as much as 1 to 2%. Please keep in mind that any reduction of boiler pressure reduces the specific volume of the steam in the boiler, and effectively reduces the boiler output. The team should therefore consider the possible consequences of pressure reduction carefully, before proceeding with this measure. Pressure should be reduced in stages, and no more than a 20% reduction should be considered.

Variable Speed Control: Variable speed control is an important means of achieving energy savings. Basically, combustion air control is affected by throttling dampers fitted at forced and induced draft fans. If the load characteristic of the boiler is variable, the possibility of replacing the dampers by a VSD should be evaluated with a boiler specialist or boiler manufacturer.

The brewery team can collect data to optimize boiler efficiency by recording and tracking boiler performance to ensure good operation. The following tables can be used to maintain efficiency in addition to monthly boiler maintenance:

Sample Boiler Data Collection Form

Boiler Name/ Location	Boiler Type	Age	Purpose- Steam heat or hot water heat	Date last update (Name)

Boiler Maintenance Checklist

Description	Comments	Monthly Maintenance
Flue gases	Measure and compare last month's readings flue gas composition over entire firing range	
Combustion air supply	Check combustion air inlet to boiler room and boiler to make sure openings are adequate and clean	
Check fuel system	Check pressure gauge, pumps, filters and transfer lines. Clean filters as required.	
Check belts	Check belts for proper tension.	
Check for air leaks	Check for air leaks around access openings and flame scanner assembly.	
Check all blower belts	Check for tightness and minimum slippage.	
Check all gaskets	Check gaskets for tight sealing, replace if do not provide tight seal	
Inspect boiler insulation	Inspect all boiler insulation and casings for hotspots	
Steam control valves	Calibrate steam control valves as specified by manufacturer	
Pressure reducing/ regulating	Check for proper operation valves	

Boiler Pressure and Temperature Log

Item #	Boiler Checkpoints	Units	Readings (notes)	Date
1	Type of Boiler			
2	Steam Pressure	Kg/cm2 (g)		
3	Steam Quantity	TPH		
4	Steam Temperature	0C		
5	Fuel Used (oil, gas, coal etc.)			
6	Fuel Quantity	TPH		
7	Feed Water Temperature	0C		
8	Flue Gas Temperature	0C		
9	Ambient (room) Temperature	0C		

Review the following points when evaluating a new boiler system for your facility:

- Pressure vessel design – When reviewing various boiler designs/types consider the pressure vessel design. Water circulation (forced or natural), low stress and accessibility are key criteria for proper pressure vessel design. The boiler should include a proper heat exchanger. Fully accessible maintenance points for ease of inspection and low maintenance costs are also important factors to seek out. For example, ensure boiler maintenance can be performed readily by comparing tube length with working space within the plant footprint.
- Number of boiler passes - The number of boiler passes simply represents the number of times the hot combustion gas travels through the boiler. A boiler with two passes provides two opportunities for the hot gasses to exchange heat to the water in the boiler. A 4-pass unit provides four opportunities for heat transfer. The 4-pass will have higher efficiencies and lower fuel costs. Fire tube boilers are classified by the number of passes the combustion gases make through the water to be heated into steam. So in a 2-pass fire tube boiler, half of the tubes have hot combustion gas passing from left to right. As the gasses exit these tubes they are redirected into the second half of the tube, making a second pass traveling right to left.
- Maintenance costs - Review maintenance costs carefully. The current unit may be costing money in various ways, which may include emergency maintenance, downtime, difficult-to-find parts and burner issues. Evaluate current maintenance costs to that of the proposed system.
- Repeatable air/fuel control - The efficiency of the boiler depends on the ability of the burner to provide the proper air-to-fuel mixture throughout the firing range consistently without the need for complex set-up or adjustments. The burner should also be able to provide suitable turndown (ability of the boiler to achieve a wide range of output) and low excess air which will improve boiler efficiency.
- Fuel-to-steam - When evaluating a boiler purchase, ask boiler vendor to go through the fuel-to-steam or fuel-to-water efficiency calculation to verify that it is realistic and proven. Review the type of boiler being evaluated to check if the unit's performance will be consistent and repeatable.

Boiler Checklist Evaluation

Item #	Boiler Evaluation Checklist	Reviewed	Remarks	Issues
1	Pressure Vessel			
2	Number Boiler Passes			
3	Maintenance Costs			
4	Air/Fuel Control			
5	Fuel – to steam (Efficiency)			
6	Other			

When reviewing an efficiency guarantee or calculation, check the excess air levels. If 15% excess air is being used to calculate the efficiency, the burner should be of a very high quality design with repeatable damper and linkage features. You should ask the vendor to recalculate the efficiency at realistic excess air values if necessary. Designing, installing and commissioning a new boiler system is a specialized project that needs to involve the supplier.

NOTE: The following items are intended to assist with improving efficiency through boiler maintenance steps and depending on the location may not be an inclusive list. All facilities must be aware of any codes, regulations and insurance requirements that are required in order to safely operate a boiler at a given location.

- Drain boiler, tag valves and controls. DO NOT attempt to remove a manhole cover without first properly venting the water or steam side of a boiler to the atmosphere. Prior to opening or entering a boiler, it must be at atmospheric pressure. To protect the boiler from unnecessary stresses the boiler water temperature should be allowed to reach the boiler room temperature before draining.
- Brush all tubes clean of scale.
- Brush plate surfaces clean, use vacuum cleaner.

- Clean ducts, main fire tube and flue passages.
- Check and replace worn or damaged insulation. Repair damage and remove debris.
- When the boiler has cooled to the ambient boiler room temperature, wash and flush boiler.
- Refill boiler with water and chemicals.
- Examine all steam and water line to controls to determine that they are clear of scale and arranged to insure proper control operations.
- Clean stems and shafts, and tighten packing nuts on valves and pumps.
- Replace old gaskets before reassembling.

Best Practices - Boiler Heat Recovery

This section provides information on control techniques and measures that are available to mitigate energy costs and greenhouse gas (GHG) emissions from industrial and commercial boilers.

Industrial equipment and facilities such as boilers, incinerators, and process plants generate heat when used. Some heat is actually discharged and thus wasted. Waste heat is heat discharged from this process into the environment even though the heat can be tapped for useful purposes. It presents great opportunities for heat recovery and fuel savings is the most obvious benefit of waste heat recovery. This is a key motivating factor for plants to consider given the significant opportunity in cost and energy savings.

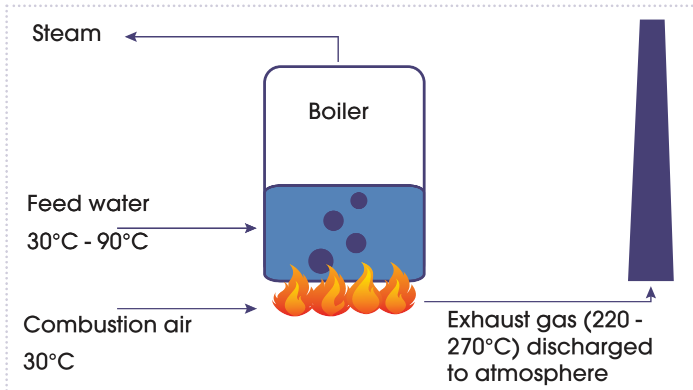
Energy efficiency can be increased by using waste heat gas recovery systems to capture and use some of the heat from the flue gas. The most commonly used waste heat recovery methods are preheating combustion air and water heating. Heat recovery equipment includes various type of heat exchangers (economizers and air heaters), typically located after the gases have passed through the steam generating sections of the boiler.

Our focus will be on economizers given they are more widely used and they do not adversely impact the combustion air temperature and the resulting NOX formation. Economizers are basically tubular heat transfer surfaces used to preheat boiler feed water before it enters the steam drum or furnace surfaces. Economizers also reduce the potential of thermal shock and strong water temperature fluctuations as the feed water enters the boiler.

The economizer recovers heat from the boiler exhaust gas and is used to pre-heat the boiler feed water. Capturing this normally lost heat reduces the overall fuel requirements for the boiler. This is possible because the boiler feed-water or return water is pre-heated by the economizer; therefore, the boiler's main heating circuit does not need to provide as much heat to produce a given output quantity of steam or hot water.

The concept of waste heat recovery can be illustrated by looking at the boiler system. Feed water enters the boiler to produce process steam. The energy for the steam production normally comes from the combustion of diesel or fuel oil, which produces an exhaust with a temperature of about 220 to 270 °C. For older boilers, the temperature of the exhaust may be even higher. The exhaust flue gas, which still contains a substantial amount of waste heat, is discharged directly to the atmosphere. As a result, energy is wasted.

Steam Principle

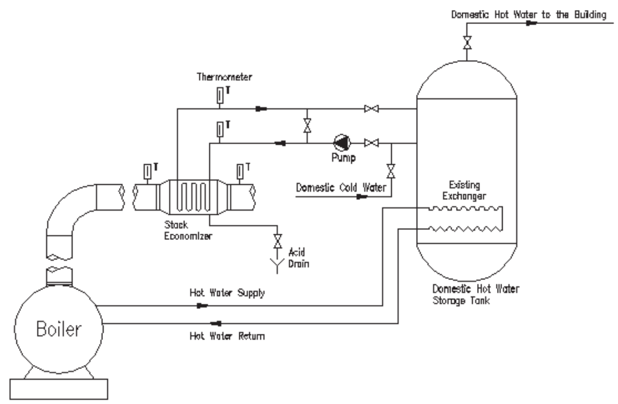


The graphic presents a process flow diagram of a typical industrial boiler system. Combustion for heat generation begins in the boiler burner system and the heat is transferred to the water in the boiler. The boiler produces steam and hot water for industrial process applications. Boilers can utilize an economizer to preheat the process water before it is fed to the boiler using waste heat from the exhaust gas.

Boiler Efficiency Rule of Thumb: A 4°C reduction in flue gas temperature will improve boiler efficiency by about 1%. The waste heat from the flue gas can be used to preheat boiler feed water, preheat boiler makeup water and heat process water/fluids.

Operators of economizers must consider potential corrosion problems, particularly in fuels containing sulfur. Moisture containing corrosive sulfuric acid is likely to condense on any heat exchanger surfaces that fall below the acid dew point. This usually occurs near the inlet of the combustion air or feed water to be heated.

Process Flow Steam System[7]



Each boiler has its specific limit of low flue gas temperature, which should be determined individually if supplementary heat exchange is being considered. Since the flue gas temperatures are decreased at lower loads, economizers often have some form of by-pass control that maintains the flue gas temperature above a preset minimum.

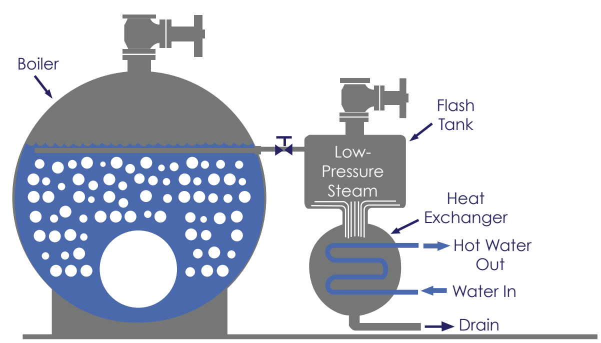
Condensing economizers can increase the boiler efficiency by 10%-15%. To optimize their performance the return water temperature from the heating system should be no more than (49 °C) and less than (41 °C) if possible. These can be used on gas or low sulfur fuel oil boilers, but it is important that the water temperature after the economizer is raised to at least (54 °C) to prevent condensation of the flue gases in the boiler. These economizers can improve the effectiveness of reclaiming flue gas heat. They cool the flue gas below the dew point. Thus they recover heat from the flue gas and heat from the moisture which condenses.

When steam transfers its heat in a manufacturing process, heat exchanger, or heating coil, it reverts to a liquid phase called condensate. An attractive method of improving boiler efficiency is to increase the condensate return to the boiler. Energy savings come about from the fact that most condensate is returned at a very hot temperature, compared to the cold makeup water that must be heated. A return condensate system must be a function of the specific boiler and water/condensate quality, but essentially involves a new distribution line configuration.

The energy savings is the energy contained in the condensate being returned. The energy efficiency improvement for a particular boiler is, therefore, the ratio of kj/hr (BTU/hr) saved from the condensate return to the original kj/hr (BTU/hr). heat input to the boiler. Overall cost savings accrue from the fuel savings due to the efficiency improvement, plus the value of the reduction in the cost of make-up water, sewage disposal, and water treatment chemicals.

Blow-down contains energy, which can be used instead of being wasted. This waste heat can be recovered with a heat exchanger, a flash tank, or flash tank in combination with a heat exchanger. Blow-down can be either intermittent bottom blow-down or continuous. Use of continuous rather than intermittent blow-down saves treated boiler water and can result in significant energy savings. The higher the blow-down rate and boiler pressures, the more attractive the option of recovering the blow-down becomes. Any boiler with continuous blow-down exceeding 5% of the steam rate is a good candidate for considering blow-down waste heat recovery. Manufacturers specified that a 1 % thermal efficiency can be achieved by this method. For example, an efficiency improvement of over 2% can be achieved at a 10% blow-down rate on a 1034 kpag or 150 psig boiler.

Boiler Steam Recovery



This drawing shows Flash Steam recovered for the steam distribution system and the hot blow-down condensate flowing into a heat exchanger to pre-heat incoming make-up water.

NOTE: Installing an economizer or blow-down heat exchanger is a project that requires external resources to design, and install. This work should be performed by qualified engineers, suppliers and installers.

The following items should be checked with the supplier:

- Cost of heat recovery system (materials and installation).
  - Detailed cost specification
  - Detailed overview of necessary materials to execute tests by supplier
- Time needed for installation by supplier.
  - How much downtime of the line is needed to implement heat recovery system?

- Actions needed by plant to assist with installation.
    - Is any assistance by plant personnel needed during the installation?
- Commissioning procedure
    - How many test runs would be needed to verify successful implementation?
- The suppliers calculated energy and cost savings
    - Detailed calculation of energy and cost savings.
- How does the supplier guarantee results?
    - How does the supplier measure energy savings?
- How does the supplier guarantee these savings?

The table outlines the some key points to discuss with your supplier when considering industrial heat recovery equipment.

Boiler Efficiency Checklist

Item #	Heat Recovery Checkpoints	Comments	Notes
1	Hot flue gas or other	Quantity, temperature, pressure and composition	
2	Heat recipient characteristics	Timing, quantity and temperature	
3	Max permissible pressure drop	Measured for the plant to which the heat recovery equipment is being fitted. Ideally, consult the original supplier or manufacturer.	
4	Access or space	For installation and maintenance.	
5	Bypass provision	To facilitate maintenance without plant shutdown.	
6	Heat exchanger design and materials	Taking into account operating temperature and the presence of contaminants.	
7	Impact on plant	Any modifications to accommodate heat recovery.	
8	Control Requirements		

After all information is received from the supplier, the overall business case should be evaluated. Therefore the following costs should be taken into account:

- Investment costs for heat recovery system. Costs based on the proposal submitted by the supplier.
- Material needed for testing and commissioning.
- Downtime needed for installation, testing and commissioning. What are the costs for the fact that there can be no production during this period? Based on the answers from the supplier, together with the supply chain department, the costs of this downtime should be calculated and used in the evaluation.
- Plant personnel needed for assistance during installation, testing and commissioning. If special plant personnel is needed for the installation and testing, and meaning these employees are not available for other work, the cost of these employees should be taken into account as well.

This all sums up to a total cost needed for purchasing, installing and testing of a heat recovery system. Based on these total costs and the provided data about energy and cost savings, a business case evaluation should be set up together with plant management and the financial department(s) and funding should be requested.

This means that the payback time of the project should be determined. Payback Time can be thought of simplistically as the time required for the savings generated by a project to pay back the initial investment. One relatively easy formula for determining Payback Time is Total Project Cost / Total Financial Savings Realized per unit time (usually years). More involved payback formulae consider the time value of money, expected lifespan of a project or other factors.

After a positive evaluation of the business case and after the funding is approved, the heat recovery system can be purchased by the purchasing department. Special attention should be paid in the contract with the supplier about the guarantees the supplier can give about the savings, and how they will prove these savings are achieved.

Best Practice - Condensate Recovery

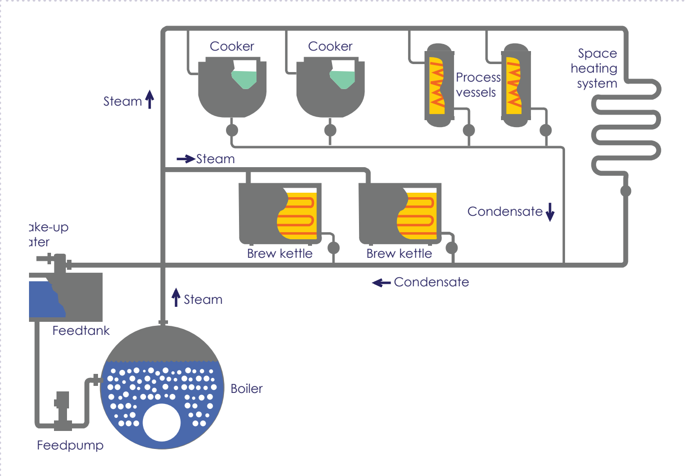
When steam transfers its heat in a manufacturing process, heat exchanger, or heating coil, it reverts to a liquid phase called condensate. Increasing the condensate return to the boiler is another way to conserve energy.

Condensate is distilled water that is formed when steam is condensed. Ideally, all produced steam should return to the boiler in the form of hot condensate, requiring no additional water to produce steam or heat to extract water from ambient temperatures to condensate.

The condensate return system is the return portion of the steam system. Condensate is the liquid residue of steam that is used in heating equipment such as brew kettles, mash tuns, CIP installations, hot water heaters, etc. It also comes from steam that condenses out in steam pipes due to heat loss from steam transport or lack of insulation.

The boiler feed water system is the input system for the boiler, or the purified and treated water that is pumped into the boiler. The condensate system feeds into the boiler feed water system. In many cases these two systems are merged so a single set of equipment can perform both condensate and feed water system functions. Makeup water is treated water added to the feed water or condensate system to compensate for system losses. The following graphic represents an example steam system, which shows the different components.

Steam System Diagram



Condensate and feed water systems perform the following functions:

- Filling the boiler system and replacing water that is lost
- Collecting and returning condensate from steam using equipment
- Draining liquid water from steam lines and idle equipment
- Injecting water into the boiler against the boiler's internal pressure
- Purifying and/or treating the boiler water to prevent damage and inefficiency in the boiler and steam using equipment
- Preheating feed water, usually with recovered heat
- Recovering heat from condensate, such as the heat of condensate flash steam
- Creating a vacuum in a condensate return system to improve condensate flow and to improve condensate flow and temperature control of steam heating equipment

Each of these functions consumes energy or affects the efficiency of the boiler system.

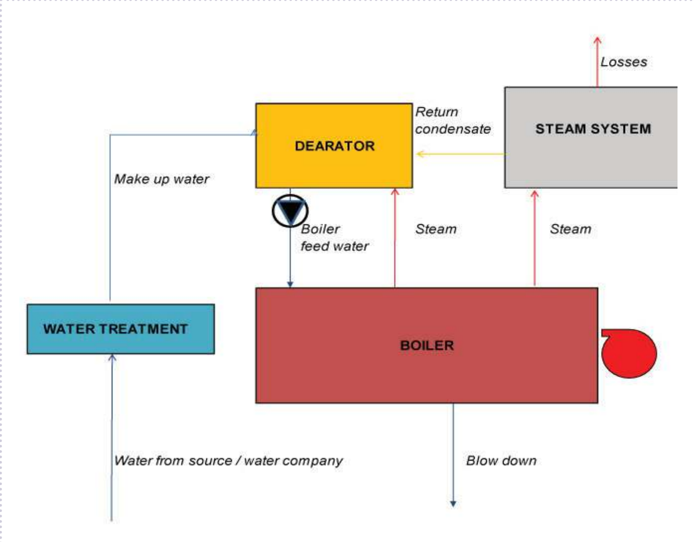
Condensate systems consist of a condensate tank or receiver and a system of pipes that lead condensate from the steam to the tank. Satellite condensate receivers are sometimes installed in larger systems, which pump condensate to a primary condensate receiver located in the boiler room.

Returning hot condensate to the boiler has several benefits:

- As more condensate is returned, less make-up water is required.
- Saving fuel, makeup water, chemicals and treatment costs. Additionally, more steam can be produced from the boiler.
- Less condensate discharged into a sewer system reduces disposal (sewer) costs.
- Return of high purity condensate reduces energy losses due to boiler blow down.
- Significant fuel savings occur as most returned condensate is relatively hot (54°C to 107°C), reducing the amount of cold makeup water (10°C to 16°C) that must be heated.

A simple calculation indicates that energy in the condensate can be 10% to 20% of the total steam energy content of a typical system. Reducing this loss would mean significant energy savings.

Schematic Overview of A Standard Steam System



A simple way to calculate the condensate return is to determine the difference between makeup water and feed water, divide this by the feed water, and multiply by 100%.

Maximizing the return of hot condensate to the boiler reduces the operating costs of the boiler(s). The best operating plants return 80% to 90% of the steam generated as hot condensate. Average bottling plants will return 70% to 80%, and the below average plants return below 70% or less. Increasing the amount of hot condensate returned to the boiler reduces energy and water cost and improves the overall steam system operation for the entire plant.

Hot condensate is returned to the boiler, retaining approximately 10% to 20% of the energy carried by the steam. For every 10% of the condensate returned to the boiler feed water system, boiler fuel consumption is reduced by approximately 1.5%. Since energy costs for steam are almost half of total energy costs, the savings for returning condensate are significant.

Saved energy results from not heating makeup water used to replace hot condensate that is sent down the drain or lost as vapor. For example, if a liter of condensate has a temperature of 80 °C and is not returned, a liter of ambient water is used to make up for the lost liter of condensate. The energy saved is the additional energy that would be used to heat one liter of water from 20 °C to 80 °C (temperature of the makeup water usually averages around 20 °C).

From this example, it is evident that maximizing the return of condensate and keeping the condensate as warm as possible as it returns to the boiler feed water system is highly important.

If the team identifies the percentage of condensate that is returned on a daily basis is below 75%, an action plan will need to be developed. This percentage is the minimum to achieve if no direct steam contact is used in the process. The best systems return 85-90% condensate.

The team should develop a plan with the following items:

- Set targets and time frames to improve condensate return. (For example; improve condensate return from 60% to 65% in 8 weeks and 70% in 16 weeks and be at or near 80% in 24 weeks. Or keep the condensate percentage above 75% continuously).
- Review the steam system overview with a heavy focus on the condensate return system. The team should use steam system drawings, layouts or flow charts that were developed for identifying steam leaks and condensate return system. The condensate drawings will include all condensate piping, heat exchangers, hot water heaters, steam traps, coffee cookers, hot fill equipment etc.
- Identify where condensate can be lost. Special focus should be given to condensate leaks, failing steam traps, steam leaks, blowing steam vents, and direct steam injection.
- Provide equipment data where possible, contact vendors, suppliers and maintenance firms to supply missing data and to provide guidance on proper sizing and application parameters.
- Develop a flow chart of the condensate system and checklist of items that make up the condensate system.

Condensate System Audit Checklist

Location	Item	Use	How can condensate be lost?

- Identify all places were condensate can be lost and add them to the steam users table.
- Assign special team members and stakeholders to identify areas in the condensate system that require attention, repair, replacement or addition.
- Prepare maintenance work orders or develop capital projects and implement fixes to the condensate system.
- Monitor each repair, upgrade or modification to the condensate system to verify that condensate collection is improving. This action should take place on a regular basis and be documented to ensure that the fix can be reviewed in the future if issue with the condensate system arises.

The team should conduct a monthly survey to check locations where condensate can be lost. The team should follow the complete steam and condensate system lines and check for losses, making use of the steam and condensate survey and tables that were developed earlier in this guideline.

If the team identifies locations with direct steam injection, investigate the possibilities of using heat exchangers or other solutions. When condensate is drained, investigate the possibilities of reusing the drainage and see if the condensate can be returned to a receiver.

Common Areas and Causes that Condensate Can Be Lost In A Steam System

- *Ensure that the condensate pumps (if used) are properly sized to the correct net positive suction head (NPSH).*
- *Consult with the supplier that provided the equipment or with your boiler maintenance technicians to determine if your condensate pumps are sized properly and are functioning in a proper manner.*
- *Failure to size the pump for the proper NPSH will cause the pump to cavitate damaging pump seals and impeller.*
- *Check the pump to verify that the temperature rating for the condensate pump is designed to collect condensate at atmospheric saturation temperature of 212 °F or 100 °C if the pump is not sized to handle these temperatures the pump will fail to operate properly.*

The condensate system will produce carbonic acid as a result of excessive carbon dioxide in the system. The highest concentration of carbonic acid will be in the condensate return lines as carbon dioxide dissolves in cooling condensate.

Most breweries today have condensate lines installed with schedule 80 steel pipe and threaded connections. When carbonic acid attacks the pipe and joints, the steel will deteriorate and create leaks. During the monthly survey all condensate piping will be checked to ensure that leaks have not formed.

To slow condensate leaks from carbonic acid or to prevent leaks from occurring insulation, stainless steel pipe and valve should be installed on the condensate system. Also, wherever possible welded connections should be used on condensate systems and threaded connections should be avoided.

Insulation allows the collected hot condensate to retain the majority of its heat on the way back to the boiler feed water tank. The condensate system should insulate

Calculate current condensate return

Calculate the current condensate return by using the formula in the examples below:

Example 1: Steam flow meter, make up water meter installed, boiler blow-down meter

Measure total steam flow for 24 hours and convert to water units either kilograms, cubic or meters (X);

Measure total make up water flow for 24 hours to the boiler feed water tank (Y) and convert to either kilograms, or cubic meters;

Measure the total amount of boiler blow-down for 24 hours and convert to water units either kilogram, or cubic meters (Z);

Formula:

$$\%\text{Condensate Return} = \frac{((Z + X)-Y)}{(X + Z)} * 100$$

Example 2: Make up water meter, boiler blow-down meter, fuel meter

Total fuel usage for generating steam. Use design data provided with boiler to calculate estimated steam flow based on fuel usage (X);

Measure total make up water flow for 24 hours to the boiler feed water tank (Y);

Measure the total amount of boiler blow-down for 24 hours (Z);

Formula:

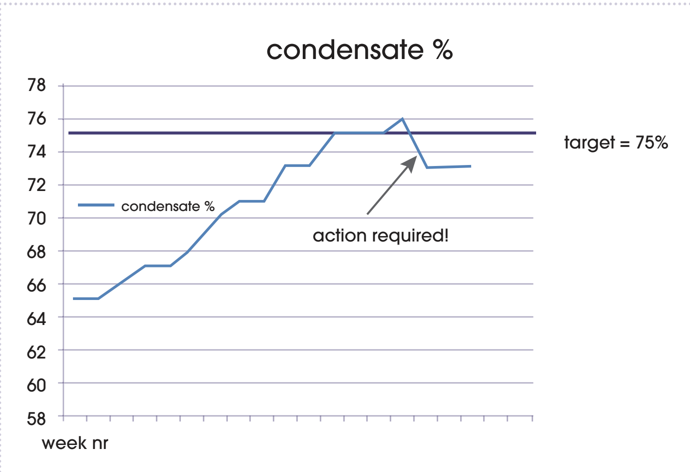
$$\%\text{Condensate Return} = \frac{((Z + X)-Y)}{(X + Z)} * 100\%$$

all equipment over 50 °C. The following items should be considered for insulation:

- Condensate lines
- Condensate tanks
- Valves
- Some steam trap types

A major source of condensate loss is steam leaks. Leaks result in additional fuel and water to be used to generate steam that is lost to atmosphere (refer to steam leak guide line for more information on identifying and fixing steam leaks). Fixing a steam leak is the best low cost item that you can perform to improve overall steam system energy efficiency.

Monitoring Condensate Return



Continue monitoring the makeup water and feed water use. Develop a monitoring system that checks the percentage of condensate return on a weekly basis. Instruct the boiler maintenance crew to make up water, blow-down and feed water samples, and monitor the fuel use every week on the same day. The team should calculate the condensate return percentage based on the reported data and monitor data in a condensate log and graph to analyze trends.

3.4 Food Service

Many craft brewers have brewpubs, restaurants or food service establishments associated with the company. In general, always look for ENERGY STAR rated or high-efficiency appliances and fixtures when purchasing or replacing equipment in order to lower energy costs during operation. Though these may cost slightly more initially, most ENERGY STAR or high-efficiency appliances and equipment usually will pay you back in lower operating costs.

This section outlines items that are simple and inexpensive updates, all the way through full equipment replacement. There are also checklists and operational procedures your establishment can use to optimize and reduce energy use with running a food service establishment.

The National Restaurant Association has developed the Conserve Sustainability Education Program. It is an excellent online resource to help restaurants reduce operating expenses and leave a lighter footprint on the environment. Many of the ideas presented in this section are from the Conserve program.

Best Practices - Refrigeration

The following items can be installed inside the brewery to optimize energy used in refrigeration:

- Use strip curtains, plastic swing doors, or automatic door closers on walk-in refrigeration and freezer units. These barriers block warm moist air from entering the units when you open your door. Strip curtains used in busy kitchens can reduce compressor runtime – the heaviest user of energy within a refrigeration unit. Ensure strip curtains cover the entire door opening for optimal effectiveness – missing pieces or gaps within a strip curtain means warm moist air is entering your units. Check with your local utility to see if they may offer rebates for these upgrades.

- Buy night curtains for display cases and open-case refrigerators. These are fairly inexpensive and work well to trap cold inside when the business is not open.
- Replace door seals if the doors are not airtight and you feel cold air escaping.
- Realign or rehang entry doors if seals appear in good condition but there are still gaps between the door and the opening.
- Shade the remote condensers on large refrigerators and freezers. These are typically installed on the roof and support a walk-in sized unit. Some shade paneling on the remote condenser will increase its efficiency.
- Insulate the lines between a remote condenser and the walk-in unit. Similar to insulating water pipes, this is a simple way to reduce energy loss between the two units.
- Install compact fluorescent lights (CFL) or light emitting diodes (LED) lights inside your refrigeration units. In addition to using less energy than traditional incandescent bulbs, they produce less waste heat that must be removed from your refrigeration unit, area, which reduces your energy use even further.
- Install motion-sensing switches in walk-ins. If the unit has a wall switch, install a motion activated switch to prevent the light being on when no one is inside.
- Upgrade fan motors in walk-in units. Look specifically for Electrically Commutated (ECM) motors. Rebates are commonly available for this upgrade and should be done before failure of an existing fan.
- Purchase ENERGY STAR rated ice machines, refrigerators and freezers where possible. There may even be incentives or rebates available through your local utility to help offset the initial costs of such equipment.
- Consider replacing inefficient units – most refrigerators and freezers manufactured prior to 1993 use significantly more energy than newer models. ENERGY STAR has a site to calculate energy use and savings for replacing old refrigerators.

After completing some of the capital investments listed above, there are some best management practices that, if implemented consistently, will result in continuous optimizing the efficiency needed for refrigeration.

- Minimize the amount of time the door is open. Minimize the number of trips into walk-in units. Do not prop the door open.
- Keep the auto-closer on the door maintained and lubricate the door hinges.
- Set the appropriate temperature, don't over cool or freeze goods.
- Keep heat sources such as ovens and dishwashers away from unit. If mobile, keep out of direct sunlight.
- Allow circulation near unit. Keep material away from condenser coils and if movable, leave a few inches between the wall and unit.
- Keep coils clean – both for the cold one inside the unit (evaporator coil) and the hot one outside the unit (condenser coil). Hardware stores sell brushes to make this easier and never use caustic cleaners on either of these coils!
- Inspect and set defrosting cycles. Most units have auto-defrost cycles, find the timer or clock that controls the frequency and set to the minimum amount needed to keep frost from building up. A good starting setting is 15 minutes, four times a day.
- Check refrigerant and keep refrigerant fully charged. Running a unit with too little refrigerant requires more energy and can wear out the compressor. Typically a sight glass or bubble window is mounted near the condenser for these checks.
- Try turning off the refrigeration unit's door heaters. These built-in heaters prevent frost and moisture buildup around the doors. In some geographical areas, these may be required. If either frost or moisture forms around the doors after turning the door heating off, turn them back on.

Best Practice – Tankless Water Heaters (On-Demand Hot Water)

The need for hot water within the restaurant operation requires either electric or gas fired heaters. The traditional means to provide this water has been a 40- to 75-gallon tank with a heating element that would heat and store hot water for use within the facility. An alternative to the traditional way to heat water is tankless or on demand hot water heating sources.

The traditional hot water heater collects water in a tank and heats the water to a desired temperature (120 °F to 140 °F). Over time as the water is used the tank is replenished and the water heated to required temperature. During periods when hot water is not required the tank loses heat and needs to engage the heating element to maintain the temperature set point. It is during these times that energy is wasted.

The tankless water heater does not store water. A tankless water heater incorporates technology that will only heat water that is required for a given application. The benefits to using a tankless or on-demand water heater results in energy savings over the traditional water heater by only using energy on demand when hot water is needed. When energy is only used when needed and not used to maintain a set point, less energy is consumed over time for the same application. On average the savings can range from 10% to 40% depending on water use and flow rates. Even though energy is saved when using a tankless water heater, the initial cost to purchase and install this technology can be as 2 to 4 times the cost of a traditional water heater. When considering a tankless water heater the following items should be considered:

Pros:

- Energy savings in that can range from 10% to 40% over traditional hot water heaters
- Less footprint required than hot water tank
- Heater can be located closer to the user
- No flooding risks
- On average tankless water heaters have a longer service life then hot water tanks
- Potential tax credits

Cons:

- Cost can range from 2X to 3X traditional tank hot water heaters
- May require larger gas line /separate venting requirements
- Annual servicing may be required
- Minimum flow rate required to operate properly
- Installation cost / code requirements more expensive than hot water tanks

Best Practices - Cleaning/Sanitization

The following items are capital improvements that can be installed for the brewery to optimize energy used in cleaning and sanitation processes:

- Installing a new or replacing your existing hot water heater with an ENERGY STAR rated or high efficiency water heater may well be the most energy efficient item you can do for this area. The lower lifetime operating costs of condensing water heaters, tankless water heaters, and (of course), condensing tankless water heaters will well outweigh the slightly higher initial cost of such units. Depending on your requirements, there may be an opportunity to install multiple smaller high-efficiency units throughout your establishment. Check with your local utility to see if there are incentives or rebates available to help offset the initial purchase cost for such appliances.
- Consider installing a high-efficiency (low flow) pre-rinse spray valve for your dishwashing process. In addition to saving water and waste water discharge, a low flow pre-rinse spray valve will reduce the overall energy needed to heat the water needed for your dish washing purposes.

As for best management practice, the most important thing to do is to ensure there are no leaks, especially hot water leaks, inside the establishment.

Best Practices - Kitchen Area

The following items are capital improvements that can be installed for the brewery to optimize energy used in the kitchen area:

- If your establishment uses steam kettles, invest in one with insulation and a lid, even if it is slightly more expensive. The overall energy use for these will pay off quickly.
- Invest in high-efficiency gas fryers, which can use up to 50% less energy than a low-efficiency gas fryer.
- Consider upgrading to a convection oven or steam/convention oven from a standard oven to

increase both the speed of cooking your food, as well as increasing the efficiency of the overall unit.

- Look for ENERGY STAR rated equipment for warming trays or hot food holding containers.

Best practices to reduce energy use in the kitchen are simple and easy. But the key item here is to make sure they are done consistently.

- For steam kettles, cover the lid! Merely covering the lid can reduce energy use for these appliances by 50%.
- Install broilers as close to a range as possible, to reduce energy needed to keep the kitchen cool.
- Turn off the ‘backup’ fryer when you don’t need it and you can reduce four hours daily of standby time. Deep fryers are typically idle more than 75% of the time, even in high-volume food service establishments.
- Consistently inspect gas lines for leaks
- Completely turn off, or turn off half of the griddle, steamer, range, and oven during slower service periods. Eliminating only three hours a day of standby time can save up to $250 per year, per unit.
- Do not preheat your oven or other appliances until you need to use it. Reducing the time your oven or other appliances are on ‘standby’ or ‘backup’ will lower energy costs significantly.
- Install motion sensors or timers for lighting in areas of lower traffic, such as closets, storage areas or break rooms.
- Get rid of old back-up refrigeration or freezer units. If you are keeping old units plugged in and on because they’re ‘free’, consider the significant energy costs you are paying to keep those inefficient units running.

Best Practices - Dining Room

The dining room is the most visible area for customers and is a great place to showcase how the brewery is being responsibly energy efficient. Some capital replacement items that have quick return on investments include:

- Replacing all incandescent bulbs with more efficient lighting options – whether they are compact fluorescent, light emitting diodes, or other types. If you need dimmable lighting, install LED, CFL with electronic ballast, or cold cathode bulbs. If dimmable lighting is not needed, look at installing CFL or T5 fluorescent bulbs.
- Using LED bulbs in lighted Open/Closed and Exit signs to reduce energy use with these always-on fixtures.
- Installing motion sensors or timers for lighting in areas that experience occasional foot traffic, such as rest rooms or overflow seating areas.
- Installing skylights where possible to allow for natural lighting. In addition to reducing energy needed for lighting, there are fewer light bulbs to change for overhead.
- Selecting ENERGY STAR – rated entertainment equipment for your audio and video equipment, as well as TVs – especially the big screens. Remember to look for ENERGY STAR equipment for all your office equipment as well.
- Installing overhead fans to reduce the need for your HVAC system to be on. Fans can uniformly distribute air conditioning and heating throughout your establishment and reduce ‘hot spots’ or ‘cold spots’ in your dining room.

Best practices to continuously implement include:

- Using natural lighting whenever possible. Assuming outdoor and indoor temperatures do not differ significantly, keep curtains and blinds open during daylight house to reduce the need for artificial lighting.
- Keeping your HVAC equipment regularly serviced and maintained, and sized right for the space.

Best Practices - Parking Lot/Outdoor Seating

Opportunities to reduce energy use for the brewery’s parking lot and outdoor seating for the restaurant include:

- Installing metal halide or high-pressure sodium lamps. For lighting poles, install metal halide (preferably pulse start) or high-pressure sodium lights, which can be paired with timers and only turned on when needed. A slightly more expensive up-front option is high-efficiency induction lighting which will generally last longer than metal halide and sodium lamps.
- Upgrading to LED lights. If lighting poles are not needed, LED lighting may be adequate and suitable for the space. LEDs also have an instant on/off capability and do not require a ‘warm up’ period as metal halide and high pressure sodium lights require.

Best practices to monitor and adopt include:

- Turning off outdoor lighting when the area is not in use. This will also reduce ‘light pollution’
- Reducing or eliminating the use of external heating and air systems

3.5 Concerts and Events

The visible sustainability impact a brewery can have during large events and concerts is through the waste management program, such as recycling. Large, outdoor events which are temporary in nature can pose a problem for energy use since such events require a reliable energy source for a short period of time, and some events may even require a backup source of energy. However, there are efforts which can be taken to optimize energy use during outdoor events and concerts.

Some opportunities at concerts and events to reduce energy use include:

- If generators are needed to supply energy for outdoor events, consider using (or requesting, if using a third-party provider) biodiesel for the fuel supply.
- Explore whether solar powered fuel cells can meet all your necessary electricity needs as well.
- Depending on your geographical location, you may be able to request solar, wind, or other off-grid source of energy to power your outdoor electrical needs. These sources of energy can reduce noise and air pollution associated with diesel / biodiesel generators as well.
- Reduce the time the generator is in idle mode, if generators are used. Only start up the motor if and when it is needed.
- Consider providing food that requires low refrigeration or (re)heating needs. In addition to reducing energy needed to keep food at the optimal temperature, you can reduce or eliminate the use of electrical cables running from your source of energy to the food holding containers.
- Turning off A/V and large screen projectors when not in use and reduce the time entertainment equipment is on stand-by mode. Even minor efforts such as turning off hand held microphones in between sets will reduce your overall energy use.
- Using insulated cups for cold beverages during hot events, if feasible. This can reduce the replenishment of ice for customers, which will reduce energy needed to keep the ice cold and produce it in the first place.

section four

Onsite Renewable Energy

Renewable energy is a means by which low carbon emission sources of energy are used to supply or supplement the energy requirements of a brewery and brewpub.

Renewable energy in most cases should not be considered an energy savings application since it is only substituting delivered energy from another source such as fossil fuel supplied electricity, natural gas or diesel oil. Renewable energy will offset the cost to purchase fossil fuel and in cases of PV Solar panels will take the cost of energy to zero.

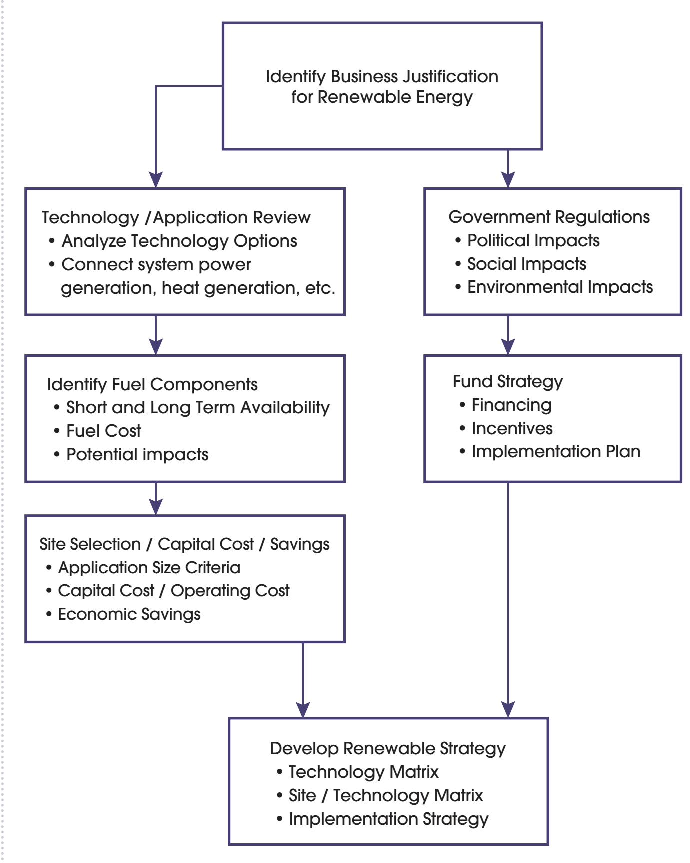
For all the advantage of renewable energy the biggest disadvantage to incorporating renewable energy is the high capital cost to purchase and install the technology and the low return on capital deployed.

Most sources of renewable energy are not considered primary energy sources due to the fact that the energy is not available on demand or can be reduced due to certain operating conditions. Examples would be wind and solar technologies. The wind needs to be blowing for wind generators to produce power and the sun needs to be shining for solar applications to perform. If either one of these conditions do not exist the energy asset is not providing value to the operation.

The following sections will outline a path that can be used to help determine how to prepare and install a renewable energy project.

The flow chart below outlines the different steps and activities that need to be considered when installing a renewable application at your facility. The steps used will vary depending on the size and type of technology; however, the flow chart provides a good way of ensuring that all aspects of the project are reviewed when renewable energy is being considered.

Energy Efficiency Evaluation Loop



A simple excel evaluation tool is provided in Appendix A to assist with preparing a renewable energy project evaluation. The table below shows an example of this evaluation.

Renewable energy projects are viable alternatives to fossil fuel energy sources and they provide a way to lower GHG emissions along with lowering direct energy cost. Renewable energy projects may be considered for a number of different reasons, including:

- Energy cost savings (lower kWh cost)
- Electrical demand management (lower peak demand kW)
- Reduce environmental impacts (GHG emissions reduction, reduce land fill material)
- Hedge against future energy cost increases
- Energy reliability and security (provide onsite energy)
- Infrastructure constraints (facility unable to expand external supply, land locked, supplier at maximum capacity)

There should be a business case to drive the project and reap the benefits. Define those business benefits, both tangible and non-tangible. The business benefit will be the foundation for the following steps in the process and providing a successful renewable energy installation.

4.1 Technology and Use Application Review

Renewable energy comes in many different forms and there is no one-size-fits-all solution. Most renewable applications start with solar energy or wind. Over the years these technologies seems to have become the technologies first mentioned when renewable energy is being considered. The reasons for this may be that they use free resources as the energy supply (sun and wind), they can be adapted to residential, commercial and industrial applications and they receive a lot of press coverage. However, when considering a renewable technology all available applications should be reviewed to determine the best fit for your location. In most cases technologies will begin to fall out favor immediately due to location and availability of fuel however, they should be considered when developing a project.

The following renewable energy technologies are typically considered and reviewed during a brewery renewable energy evaluation:

- Sun Power (PV electrical power, solar heating, CSP)
- Wind Power (wind generation – all sizes)
- Bio-mass (heat generation, power generation)
- Landfill gas, Bio-gas (heat generation, power generation)
- Waste to energy sources (heat generation, power generation)
- Geothermal (direct heating, electrical generation, HVAC)

4.2 Fuel Availability

When reviewing the different renewable technologies the availability of fuel will be one of the criteria used to determine the best renewable technology to be installed. All renewable energy fuels are not created equal. Your location will play a major role in determining the best fuel for your application. For example, a brewery in Arizona may have an advantage when it comes to solar technologies compared to a brewery located in Illinois. Both areas receive sun, but the sun intensity (the amount of energy delivered per square foot) is greater in Arizona than in Illinois. Also the amount of direct sunlight is higher in Arizona than Illinois. This difference means that the brewery in Arizona will produce more kWh for a solar installation than in Illinois. However, the brewery in Illinois may be better positioned to consider landfill gas, bio-mass or wind.

The following considerations should be reviewed when investigating renewable energy for your operation:

- Sun intensity – available sun energy, intensity and duration
- Wind – speeds at all times of the year, elevation of the winds
- Bio-mass – availability and delivery systems for wood, agricultural waste, energy corps
- Bio-gas – Municipal, industrial, agricultural waste streams, anaerobic digesters
- Waste to energy – Municipal waste water treatment sludge, industrial by-products etc.
- Geothermal – surface water, ground water potential, and deep wells

4.3 Fuel Supply and Cost

The availability of fuel is only one step that needs to be considered when investigating renewable energy applications. The delivery of the fuel is the just as important as the fuel itself. Sun and wind have no delivery system however, they carry risks that need to be studied and understood.

When the renewable energy supply is bio-mass, bio-gas, land fill gas or waste to energy sources, different criteria need to be considered when determining if this renewable energy source will fit your needs:

- Fuel supply (infrastructure in place to support fuel supply and delivery requirements for the long term)
- Cost to process, transport and deliver fuel are established and fully functional (if this is not the case are the risk known and accounted for in the fuel evaluation section)
- Have the available fuel reserves been vetted to ensure that an adequate supply is available for the life of the project (wood availability, how long is the estimated life and gas flow amounts for the land fill, what are the risks involved with the waste to energy supplier)
- Have all the competition for the fuel supplies in given areas been investigated (bio-mass, only so much fuel available in an area need to be first in, Landfill gas decays over time, how many users are on the gas supply)
- Infrastructure risks (renewable energy suppliers may not be established in a reliable network)

4.4 Size Selection and Infrastructure Impacts

The size of the system is critical to meeting the business objective for the project. Assume a brewery is land locked and has only roof space to install a PV solar application. Also assume that the largest system that will fit on the available roof space is 100kW and 500kW is needed to justify the project. This could pose a serious problem. At this step in the process, these questions will begin to surface and answers developed.

The following needs to be considered:

- Physical location off the proposed technology (open space, roof, inside existing building etc.)
- Existing infrastructure modifications that will be needed to accommodate renewable energy source (roof supports, demolition, expansions, additional land purchase, etc.)
- Code requirements, environmental impacts and other regulatory conditions (building codes, set back requirements, environmental impacts emissions, water, etc. and other regulatory conditions that will impact the project)
- Social and business risks.

4.5 Cost and Savings Review

The final step involves the review of the capital cost and savings that will be attributed to the project. When determining the cost for the project the first item that should to be considered is how the project will be financed and how company policy or culture stands for deploying capital.

The renewable energy industry offers a multitude of options to finance projects and each should be considered to determine if an acceptable ROI can be obtained. For example well over 70% of the PV solar projects installed today are done under a PPA (Purchase Power Agreement). The basic premise is that a brewery and an energy provider

Renewable Energy Comparison

Technology	Fuel Concerns	Energy Savings / Offsets	Environmental Impacts	Incentives, Rebates, Grants	Infrastructure Modifications	Capital Cost	Return on Investment	Recommendation
PV Solar	Sun Level Class 3	100kWh/day	None	Tax Credit	Yes, Roof	$120,000	4.5 years	Hold, until economics are more favorable
Solar Heat	Sun Level Class 3	50m³/m	Yes, Water	Tax Credit, Utility Rebate	Yes, Roof and Piping	$45,000	1.5 years	Move forward with Project Development
Bio-gas Cogen	300m3/month	3600m3/yr	Yes, waste water permits	Tax Credit, State Grant	Yes, Install anaerobic digester	$150,000	2 years	Move forward with detailed scope and estimate
Wind Generation	Low Wind	20kWh/m	Yes, impact study	Tax Credit	No	$75,000	10 years	Not applicable to site study discontinued
Geo Thermal	NA	NA	NA	NA	NA	NA	NA	Not applicable to site

enter into an agreement to install the necessary solar equipment and supply power to the customer (usually at a rate that is below market) for low to no capital investment to the brewery. The brewery may be required to lease a portion of their property to the provider as well as sign a 15 to 20 year agreement to purchase the power. This agreement has been used for renewable projects other than solar as well.

The traditional method exists as well where the owner designs, purchases the equipment and installs the technology. This method of installing a renewable energy project can be used for all types of technologies and systems. However, this type of invest is typically more prevalent with bio-gas, bio-mass and geothermal systems. Systems that operate on a 24-hour cycle are more consistent with existing energy systems in the plant and produce a higher return on investment with shorter payback cycles

Wind, solar and land fill gas projects are trending to the PPA or other third party financing vehicle that aligns the project for a longer period of time, with a negotiated rate for the delivered energy and a longer term commitment. In almost all cases, little to no capital is required from the brewery.

The landscape for incentives in renewable energy is changing at a rapid pace. Due to the financial crisis that occurred in 2007 – 2008 many of the renewable energy incentives have been eliminated or downsized dramatically. Current incentives at both the Federal and Local level can be found at the DSIRE web site (http://www.dsireusa.org/).

Incentives play a very important role in the installation of renewable energy projects. If incentives had not been introduced, the renewable energy market would be much smaller today. Incentives allow for the technologies to develop, build towards critical mass and become a viable competitor to fossil fuel sources.

4.6 Renewable Energy Certificates

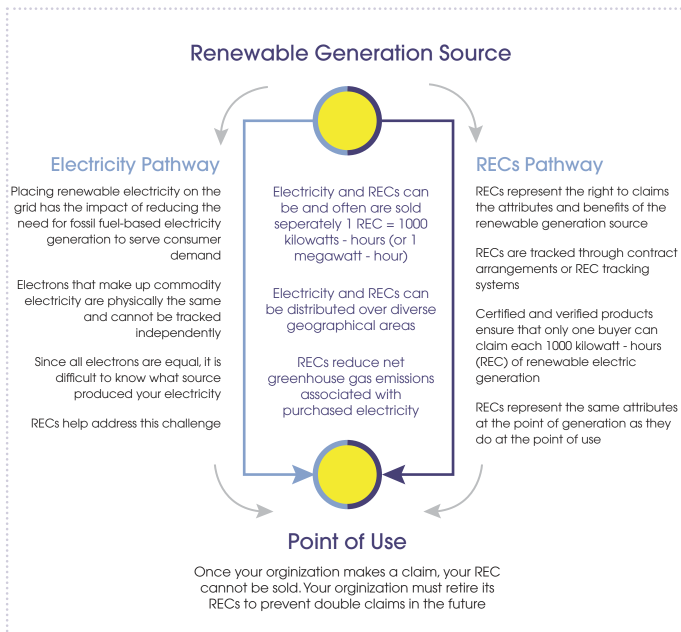
Renewable Energy Certificates (RECs) represent the environmental and other non-power attributes of renewable electricity generation and are a component of all renewable electricity products. RECs are measured in single megawatt-hour increments and are created at the point of electric generation. Buyers can select RECs based on the generation resource (e.g., wind, solar, geothermal), when the generation occurred, as well as the location of the renewable generator.

RECs are increasingly seen as the "currency" of renewable electricity and green power markets. They can be bought and sold between multiple parties, and they allow their owners to claim that renewable electricity was produced to meet the electricity demand they create.

Some of the reasons to purchase RECs include:

- Avoid the carbon dioxide (CO2) emissions associated with conventional electricity use
- Reduce some types of air pollution
- Hedge against future electricity price increases for onsite and some utility products
- Serve as a brand differentiator
- Generate customer, investor, or stakeholder loyalty and employee pride
- Create positive publicity and enhance public image
- Demonstrate civic leadership

Renewable Energy Certificates[8]



The purchase of RECs is an individual brewer decision based upon marketing potential and image enhancement. RECs are often purchased to reach a goal of zero carbon emissions. Each brewer should exhaust all opportunities to increase energy efficiency and lower operating costs before considering RECs.

section five

Brewery Case Studies

5.1 Usage and Reduction

Boulevard Brewing Company – Kansas City, Missouri

Boulevard's heating, ventilation and air conditioning (HVAC) system is designed to deliver comfort as efficiently as modern technology allows. The company's mixed-use building places a wide range of demands on the HVAC system. This challenge has been successfully met through the implementation of a zone control strategy in the Building Automation System. This system makes heating and cooling adjustments based on real-time requirements in each zone, while leaving unoccupied, non-critical zones relaxed regarding their temperature requirements. The system employs outside air economizers to bring fresh air into the building during temperate periods. Cooling on hot days is accomplished by a high efficiency central chilled water plant that utilizes a non-CFC refrigerant. Low-loss electric heating elements provide heat for the entire system during the winter.

Boulevard's new building was carefully designed to utilize natural sunlight. This is accomplished through large windows, enormous roof monitors (skylights), and light wells. Secondary light sources are high efficiency compact fluorescents and high output T5 fluorescent tubes. All exterior lighting is controlled via photocells and timers to prevent the waste of energy.

The company's location in the urban core drives a desire to be an integral part of its ongoing renewal. And it's not only the brewery that calls the central city home—a large proportion of employees live within a 3-mile radius of the brewing plant. This, of course, reduces greenhouse gas emissions by reducing the number of vehicle miles associated with commuting activities of Boulevard staff.

The green roof on the new brewhouse and packaging building reduces the heating and air conditioning loads (lowering energy consumption) by increasing the insulation value where it is needed most—on the roof. The surface also absorbs rainwater, thus reducing runoff, while sustaining a variety of plant life. The plants, in turn, reduce the overall thermal footprint of the building, absorb CO2, and produce oxygen, all positively impacting the quality of life in the surrounding area.

Deschutes Brewery – Bend, Oregon

A new 40,000-square-foot warehouse uses passive cooling to achieve 64 °F year-round. This temperature is maintained even during the summer heat without using energy-consuming refrigeration or air conditioning—cool Central Oregon night air is trapped inside by concrete walls and exterior insulation, along with cold beer in the warehouse.

In the brew house, energy recovery reduces the need for steam. All of the heat for the brew house comes from steam supplied by two new, energy-efficient natural gas boilers. Heat lost from the boiling wort (unfermented beer) in the brew kettle is recovered and used to pre-heat future batches of wort with a vapor condenser on the exhaust stack. This translates into less energy demand, lower operational costs, and faster brew times.

Two new energy-efficient, low nitrogen oxide (NOx) boilers were installed to meet current and future steam demands. Both boilers have stack economizers that reclaim heat from the flue gas to preheat feed water for the boiler.

A blow-down economizer was added to the boilers to reclaim heat from excess boiler water and is used to preheat feed water for the boiler. By preheating the makeup water, the Btu/hr input of the boiler drops while the Btu/hr output remains the same.

In the restaurant operations, a focus was placed on making energy-saving decisions such as: replacing older thermostats; installing an insulated exterior door to the cooler; installing a more efficient ice machine; using compact fluorescent bulbs; placing lights on dimmers; and keeping fans, lights and televisions off until customers arrive—all of which saves about 3000 kilowatts per month for a $200/month savings on electric bills.

Harpoon Brewery – Boston, Massachusetts

The Harpoon Brewery has distinguished itself as an energy-savvy facility in several respects. Through demand response, Harpoon can reduce 350 kilowatts of electrical demand from the grid, more than half of the brewery's normal electricity load. Harpoon and EnerNOC collaborated to develop a customized energy reduction strategy to reduce electrical demand during high demand periods. This strategy includes modifying the set points on Harpoon's chillers, rescheduling bottling processes, and making other relevant production changes.

In addition, Harpoon has taken a number of other initiatives to improve energy efficiency throughout its operations. The facility features motion-sensing lights and new, more energy-efficient temperature controls for fermenters and other brewery equipment. Harpoon also recaptures condensate from its brew kettles to save on heating hot water.

New Belgium Brewing Company – Fort Collins, Colorado

In 2010 New Belgium installed a Smart Grid, partially funded by the FortZED project mentioned below. What is a Smart Grid? A Smart Grid applies 21st century technology to the brewery's power systems. Today's electrical grid is characterized by one-way flow of information, centralized, bulk generation, and no data for consumers to use to manage their energy use. The smart grid enables the 2-way flow of both energy and information. For example, when New Belgium receives notice from their electricity provider, they can shut off non-essential functions, like the HVAC system, to reduce the load on the grid and the need for additional power generation at the utility. Likely, cooling can be reduced for a short time without noticeably affecting the ambient temperature in a room. They will also be able to integrate their variable distributed generation (solar, biogas, etc.) with the City's supply and demand.

New Belgium uses natural gas for thermal energy (i.e., heating water, creating steam) and works to conserve natural gas through recovery systems which close heat loops in the production process.

With their Steinecker 'Merlin' Brew Kettle, New Belgium is able to reduce the brewery's natural gas consumption by cutting the boil time in half. Instead of boiling from the outside in, the Merlin has a cone shaped boiler plate that flash boils the wort. The accelerated boiling reduces natural gas consumed and cuts back on water lost to evaporation.

Sierra Nevada Brewing Company – Chico, California

Carbon Dioxide Recovery and Reuse - As yeast ferments sugars into alcohol, CO_2 is naturally produced. Instead of venting that CO_2 into the atmosphere, Sierra Nevada has installed a sophisticated collection system to recover and recycle the CO_2 produced during fermentation. The system captures CO_2 directly off the top of the fermenters and sends it into the recovery system. The recovery system dries and filters the CO_2 of any impurities before compressing it for storage. The brewery recycles the recovered CO_2 back into the plant for various applications including sanitizing, moving product, and purging and pressurizing tanks. Collecting the company's CO_2 also eliminates truck deliveries to the facility and the associated environmental and financial costs.

Process Control - In order to control the brewing process in the most efficient way possible, many of Sierra Nevada's systems are extensively automated using programmable logic controllers, variable frequency drives and sophisticated instrumentation. Automation allows the company to maximize throughput while minimizing energy usage.

Indoor Energy Efficiency - Light from the sun remains the most efficient lighting available. The company takes advantage of this free and abundant light source with the use of large windows and skylights throughout the facility. For electric lighting, they have installed timers, ambient light sensors and motion sensors, even combining technologies to increase efficiency. Ballasts and fixtures have been upgraded to be more efficient. To minimize loss of refrigeration, the brewery's new cold storage warehouse has sealed loading docks and Fastrax doors have replaced the inefficient strip curtains that separate cooled warehouses from the outside. Ultimately, employee behavior has the biggest impact in energy consumption and everyone is encouraged through continuous education to take simple steps to help meet energy goals.

Heat Recovery - Brewing not only requires a significant amount of heat, but also releases a tremendous amount of heat through boiling, steam generation, and cooling hot liquids. Instead of venting this heat energy, Sierra Nevada has implemented several applications to recover and recycle waste heat: plate heat exchangers throughout the facility and heat recovery systems on brew kettles, boilers, and fuel cells.

Standing Stone Brewing Company – Ashland, Oregon

Because of energy-saving improvements Standing Stone has made, the Oregon Department of Energy has called the brewery a leader in restaurant energy conservation.

Their heat exchange recovery unit routes waste heat from brewing and refrigeration to pre-heat water, yielding a cool 10 percent energy savings.

An adjustable, louvered awning above the company's back deck limits Standing Stone's concrete building's absorption of the sun's heat. This reduces their air-conditioning use during Ashland's warm summers without blocking diners' views.

They installed an innovative energy management system to coordinate operation and increase the efficiency of the brewery's heating, cooling and lighting systems.

Standing Stone has an energy-saving variable-speed hood control system in the kitchen. This saves 22 percent of their natural gas and electricity combined, compared to standard restaurant fan systems that run at full speed consistently, affecting other energy systems and creating noise.

Through the company's "RPM" program, they give employees free bikes if they agree to commute 45 times annually, saving significant fuel, pollution and greenhouse gas emissions. Employees stay healthy and happy, too. Nearly 30 employees are participating.

The brewing company uses an electric motorcycle to get eggs from their farm and transport tools there, avoiding petroleum use and vehicle emissions.

In 2002 they installed an energy-saving variable speed hood control system for the kitchen. The system can be installed on both new and existing hoods. Kitchen fans typically run all day at 100 percent speed. However, controlling fans with variable speed drives that receive feedback from temperature and smoke sensors allows fans to slow during off-peak periods and operate with the minimum exhaust flow needed. The air conditioning system also runs less, because less cooled air is lost by venting through the exhaust fan. For Standing Stone, this meant reduced electricity use. During colder months when the restaurant is heated by natural gas, savings occur in a similar way, because fans expel less warmed air. A secondary benefit for kitchen workers is a reduction in the background noise associated with kitchen ventilation systems that usually run constantly at full speed.

Oregon's Business Energy Tax Credit program helps fund qualified energy-saving efforts. Standing Stone qualified for a tax credit of $2,089 on the $5,969 project. This 35 percent tax credit reduced project costs to $3,880. The expected combined electricity and natural gas savings amount to 22%, savings of about $1,213 per year, with an estimated payback period of 3.2 years (including incentives).

5.2 Onsite Renewable Energy

Lucky Labrador Brewing Company – Portland, Oregon

Solar Heating - When the Lucky Labrador Brewing Company decided to incorporate alternative energy into their beer-making process, they set their sights on harnessing energy from the sun. As the most cost-effective form of renewable energy, solar hot water was an obvious choice for the Portland, Oregon brewery. They contracted a Portland-based solar hot water installer for consultation and installation. With support from project engineers, the installer was able to design and specify a system for Lucky Labrador's exact hot water needs. After the design was approved by the local city planning department, the actual installation took less than one week.

Immediately after it was installed, the owners of the brewery noticed the difference. "The first week we had 3 days of sun and we got 3,407 liters of water up to 60 °C, well on the way to the 70 to 90 degrees needed for brewing. The air temperature outside was around 4 °C. Since the system can last 25 years or more, the Lucky Labrador brewery can look forward to many years of reliable performance, saving them money and the environment at the same time.

New Belgium Brewing Company – Fort Collins, Colorado

At their onsite Process Water Treatment Plant (PWTP), New Belgium uses microbes to clean all of our production wastewater through a series of aerobic (with air) and anaerobic (without air) basins. A byproduct of this process, methane gas, is harvested and piped back to the brewery, where it powers a 292 kW combined heat and power (CHP or co-gen) engine. This engine can produce up to 15% of New Belgium's electrical needs and turns a waste stream into a source of energy. It is a good example of a closed-loop system in their brewing process. But, like much that's innovative, it malfunctioned a bit in years past. Through a partnership with a locally headquartered business, however, they installed new controls equipment and the co-gen is running better than ever.

In January 2010 New Belgium commissioned a 200 kW photovoltaic array on top of the brewery's Packaging Hall. At the time it was installed, it was the largest privately owned array in Colorado. It will produce almost 264,000 kWh each year and contribute over 3% of the company's total electricity. This project was partially funded by the FortZED partnership. In 2007, New Belgium partnered with the City of Fort Collins, Colorado State University and other energy-focused companies to apply for a grant from the Department of Energy (DOE) to demonstrate 20 - 30 percent peak electric load reduction. The collaborative project will be the first phase of implementing FortZED, a long term vision for a zero energy district in downtown Fort Collins.

For New Belgium, this meant installing $3 million in new load-shedding and onsite generation capabilities, funded 50% in house, 25% by the DOE and 25% by in-kind donations. Their goal is to be able to create or shed 1000kWof electricity - almost the brewery's annual peak load – through solar PV, co-generation, metering and controls.

Sierra Nevada Brewing Company – Chico, California

Solar Power - In December 2008, Sierra Nevada Brewing Co. completed what is now one of the largest privately owned solar installations in the country. Their solar system consists of two layouts – a carport array and a roof top array. The carport array was commissioned in September 2007. It includes 2,288 SunPower photovoltaic panels, each with a 225-watt capacity, and a total potential electricity output of 503 kW DC. A single-axis sun tracking system allows the panels to follow the sun throughout the day, making the system 30% more efficient than a stationary system.

Installation of the roof top array began almost immediately after the carport system. It was completed in two phases and commissioned in December 2008. The system includes 7,688 Mitsubishi, 185-watt photovoltaic panels. The system is capable of providing an additional 1.42 Megawatts of DC electricity to the facility. Solar panels have also been installed on Sierra Nevada's onsite daycare facility and rail facility. The daycare has a 28-panel system with a 5.18 kW DC capacity that provided 100% of the center's electricity in 2010. The rail spur has 76 panels with a 14 kW DC capacity that will produce more than 100% of the rail spur's electricity needs.

The roof of a new cold storage warehouse, completed in late 2010, is slated to be covered with solar panels in 2011, adding an additional 110 kW of solar power.

Altogether, Sierra Nevada's solar systems are currently capable of producing 1.94 Megawatts DC and include over 10,000 individual photovoltaic panels. In 2010, they produced 2,635,869 kWh, or 19% of the company's total electricity needs—roughly equivalent to powering 265 average American households.

Hydrogen Fuel Cells - In 2005, Sierra Nevada became the first brewing operation in the United States to install hydrogen fuel cells. The onsite facility consists of four 300 kW fuel cell energy units that together are capable of generating 1.2 Megawatts of DC electricity. The fuel cells run on natural gas and have the potential to be more efficient by using the biogas generated at their onsite water treatment facility; they are currently exploring the infrastructure needed to make this happen. To enhance the fuel cell's efficiency, the company added heat recovery units that recover the approximately 400°C exhaust leaving the units and produce steam that is recycled back into the brewing process. The heat recovery units add 15% efficiency to the installation. In 2010, the fuel cells produced 6,639,821 kWh or 48% of Sierra Nevada's electricity needs—roughly equivalent to powering 665 average American households.

Energy From Recovered Bio-Gas – the brewing company's wastewater treatment process, described in detail in the next section, includes an anaerobic digester that breaks down organic materials in an oxygen-deprived environment and produces a methane-rich biogas. A recovery system captures this gas and sends it to fuel their boilers to offset the natural gas needed to run the system. This lowers the company's natural gas utility consumption and cost while reducing greenhouse gas emissions.

Standing Stone Brewing Company – Ashland, Oregon

Standing Stone's roof has a 4.6 kW solar system, which generates approximately 7,800 kWh of clean, local, renewable power and eliminates 10,000 kilograms of CO2 from the atmosphere annually.

Victory Brewing Company – Downingtown, Pennsylvania

In 2009 and 2010, Victory Brewing installed a total of 12 thermally protected, energy efficient fermenters whose cooling and temperature monitoring are powered with photovoltaic electricity, in order to maintain the company's ethic of low environmental impact manufacturing.

They harness the energy of the sun to power their beer-making with the installation of 345 photovoltaic panels. Installed by a nearby company, the system generates approximately 82,000 kWh of clean, green electricity each year. A system monitor installed in their restaurant at Victory Brewing Company displays live data regarding the system's energy generation for patrons to witness.

appendix a

Tool Box

Guidance and Checklists

1. Guidance – Energy Set–points
2. Guidance – Employee Engagement
3. Guidance – Insulation
4. Guidance – Lighting
5. Checklist – Energy Audit (Washington State University)
6. Checklist – Future Design Tips

Excel-Based Tools

1. Energy and GHG data collection template
2. Renewable energy cost calculator

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