Energy Efficiency Opportunities in the Canadian Brewing Industry

Second Edition, 2010

Brewers Association of Canada
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Lom & Associates Inc.

Energy Efficiency Opportunities in the Canadian Brewing Industry

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FOREWORD

Energy Efficiency Opportunities in the Canadian Brewing Industry, a joint project of the Brewers Association of Canada and Natural Resources Canada, revises and updates an earlier edition of the same title produced by Lom & Associates Inc., and released in 1998.

The purpose of this new edition is to recognize the current activities undertaken by the Canadian Brewing Industry and individual companies of all sizes with respect to energy use, greenhouse gas reductions and conservation of water; identify opportunities for improvements in efficiencies in these respective areas; and to present related industry performance trends and data where available, both in Canada and abroad.

The Guide is also intended to assist in the development and achievement of voluntary sector energy efficiency targets, under the auspices of the Canadian Industry Program for Energy Conservation (CIPEC). The Brewers Association of Canada is a member of CIPEC representing the brewing industry sector.

The long-standing and successful Canadian Industry Program for Energy Conservation (CIPEC) is a voluntary partnership between the Government of Canada and industry that brings together industry associations and companies representing more than 98 percent of all industrial energy use in Canada. Since 1975, CIPEC has been helping companies cut costs and increase profits by providing information and tools to improve energy efficiency.

Many of the opportunities for obtaining substantial energy and financial savings are often missed, even though advice is available from many sources. The barriers to energy efficiency include aversion to the risk of new technology, lack of awareness about the relative efficiency of available products, inadequate information on financial benefits or a strong preference for familiar technologies, and over-emphasis on production concerns.

The Brewers Association of Canada has a mandate to work on behalf of the brewing industry and its members to create a climate for consistent and sound economic performance. By increasing internal efficiency through investment in efficient technologies and practices related to energy and other utility use, companies can reduce their operating costs and improve their performance. In this respect, the guide offers a rationale for the sound management of energy and other utilities. The Guide is also intended to serve as a useful handbook and learning tool for technical staff new to brewery operations.

Finally, the development and release of this revised edition represents a practical demonstration of the industry's deep commitment to protecting the environment, including the reduction of greenhouse gases, and the wise management of Canada's resources.

How to use this Guidebook:

The singular purpose of this guidebook is to give you, the reader, a lot of ideas and tips about how to approach the issue of improving energy efficiency in your operations, and what to do to achieve it. This is not a scientific, theoretical book and neither is it a brewery energy management operations manual. It should serve as a practical, one-stop source of information and point you in the right direction to get the help you need. Regardless of the type and size of your operations and your specific circumstances, you should be able to get ideas from the book to successfully implement energy conservation projects in your brewery.

***Read all of it first*:**

….no matter what type of brewery operation you have and what your energy-related priority is right now. You are apt to find ideas that you can easily adapt to your own particular situation. More likely than not, those ideas may offer a synergistic solution to a particular problem. While you are reading this guidebook, free up your imagination and the spirit of innovation about which ideas you could apply in your plant.

Modern energy management involves many inter-related energy-consuming systems. Get the overall view by reading the entire guidebook first.

Please note:

Commonly, historically derived measures, such as the practically sized hectolitre – hL (100 Litres) – are used internally in the brewing industry. The usage of the Canadian barrel (= 1.1365 hL) is on the wane. For reasons of standardization and to facilitate international and between industry comparisons, **the international SI (metric) system is used wherever possible throughout this guide.**

Some BAC statistics quoted here are related to one hectolitre of beer. One hectolitre = 1 hL = 100 L. One kilolitre = 1 kL = 10 hL = 1000 L = 1 m^3. Similarly, when a measure of mass is used, such as one metric tonne [t] = it means 1000 kg, or 2204.6226 lb = 0.9842206 tons (long) = 1.10233113 ton [short]).

ACKNOWLEDGEMENTS AND DISCLAIMERS

The Brewers Association of Canada gratefully acknowledges the Industrial Programs Division of the Office of Energy Efficiency of Natural Resources Canada, represented by Ms. Tanja Stockmann, Senior Industry Officer, for the support and expert guidance, as well as for its funding in the development of this guide.

The authors express their sincere appreciation to Mr. Ed Gregory, Manager, Research and Analysis, of the Brewers Association of Canada for providing excellent project leadership and effective organizational support and help that always went well beyond the call of duty.

An Energy Guide Working Group, struck by the BAC in 2009, provided important advice aimed at improving the Guide, including its' relevance and usefulness to brewers across a range of production sizes. Their valuable comments on the manuscript and other suggestions for improvements are appreciated.

The enthused participation of many brewers in the course of the project, their volunteering of tips and ideas about best energy management practices, and responses to the energy survey questionnaires were most helpful. For that our thanks are due, in particular, to:

Charlotte Armstrong	*Labatt Breweries of Canada
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Al Genest	Great Western Brewing Company
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Ed McCallum	*Sleeman Breweries Ltd.
Hugh Mitchell	Vancouver Island Brewery
Ron Moir	Heritage and Scotch Irish Brewing
Michael Stirrup	Wellington County Brewery Inc.
Chris Wells	*Sleeman Breweries Ltd.
Kevin Wood	Drummond Brewing Company Ltd.

*BAC Energy Guide Working Group

We would be remiss not to acknowledge, with thanks, the expert graphic and layout services of Jara Zacik and Eva Puldova.

The authors acknowledge with sincere appreciation the many sources of information, listed in the Bibliography in the Appendix 10.1, from which they liberally drew in revising and updating the *"Guide".*

Disclaimers:

Every effort was made to present the information contained in the *"Guide"* accurately. The uses of corporate ad/or trade names do not imply any endorsement or promotion of ay company, commercial product, system or person. The generic opportunities as presented in this *"Guide"* do not represent specific recommendations by the Brewers Association of Canada, Natural Resources Canada or the authors for implementation at individual brewery sites. The aforementioned parties do not accept any responsibility whatsoever for the implementation of such opportunities in the breweries or elsewhere.

1.0 INTRODUCTION

When the *"Guide"* was first bilingually published in 1998, it provided the first cohesive description of what one can do in a Canadian brewery to reduce the enormous energy load that beer production entails. It obviously filled an existing need: the initial bi-lingual printing was soon gone and a reprint was produced in 2003.

Sometimes, even when the opportunities for energy savings are great, they are not utilized. The reasons fall into the familiar:

- Top management not supportive
- Energy issues not a priority
- No money and/or manpower and/or time
- No defined accountability
- Lack of information
- Was not aware of opportunities that exist
- Did not know what to do

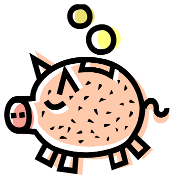
The above are samples of answers received from a survey of small breweries in Canada (by BAC – March/April 2010). This guide should help a practicing brewer or anyone interested in conserving energy in a brewery to get the information needed.

Small brewers' concerns have also been incorporated in the new edition; some of them volunteered 'best practice' tips, which they are utilizing. Many could be adopted, with advantage, by much bigger breweries as well.

An important point is the incorporation of relationships between the use of energy and generation of greenhouse gases, an issue that has been gathering increased urgency worldwide, and remains an environmental priority for the Canadian Government.

Additional guidance is given on selecting and costing projects (also with respect to risk evaluation, helpful in deciding whether to realize a project or not). It uses simple guidelines, applicable to any project, not just in energy field. As well, monitoring and measuring energy and utilities consumption and target setting is given more attention.

Tips, about what potential to improve energy efficiency may exist in breweries are often summarized under "Energy management opportunities (EMOs)", which are roughly divided into three categories:



No or low cost (housekeeping) items
– **payback period is six months or less**

Medium cost – changes to plant & equipment or buildings required – **payback period is 3 years or less**

Capital cost – principal retrofit or new equipment required – **payback 3 years or more**

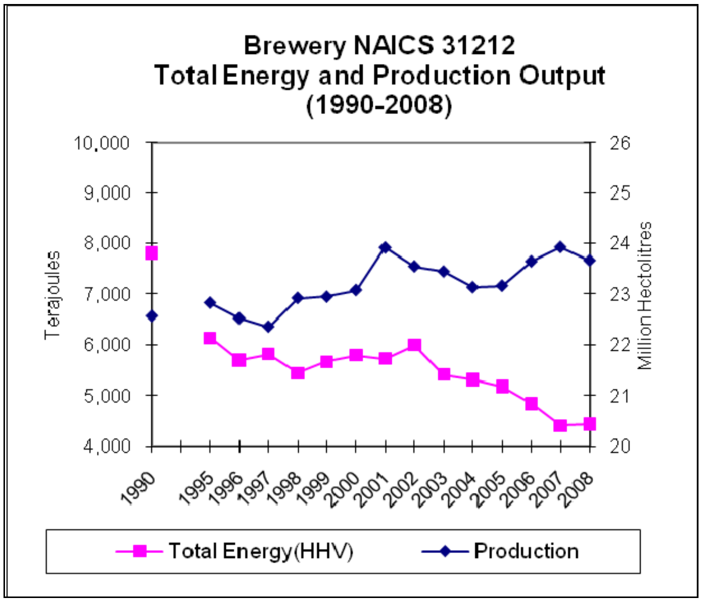
Where appropriate and available, references and case studies have been inserted into the text at logical points. In the same vein, some results from the survey of small brewers, and from the technical survey of energy use among all brewers in Canada, that preceded this revision of the "Guide", have been selected for illustration. The information provides some insight into the current status of energy conservation effort in Canadian breweries and can help policy makers to better address the needs of the brewers for technical and resource assistance.

Tips of interest particularly (but not exclusively) to small brewers are highlighted in <u>blue font.</u>

As before, the structure and content of the publication assumes that the reader has already basic knowledge of the brewery operations and processes. Yet, it is written in a way that will provide sufficient information even to members of supporting functions in breweries large and small. The point is to generate good understanding of the energy use issues by all brewery staff and obtain their support in addressing them effectively.

We wish you inspiring reading!

1.1 Profile of brewing in Canada

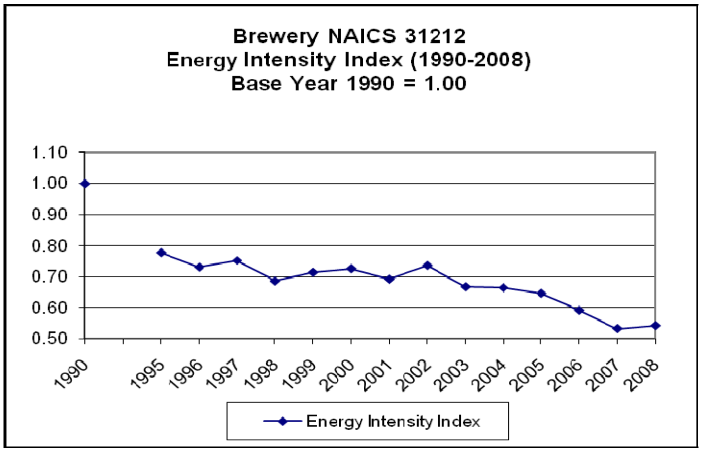


There are some 160 breweries, large and small, operating currently in Canada. The total production, to which the small breweries (i.e., those below 200,000 hL of annual output) contribute about 10%, is graphed below. The typical cost of energy and utilities amount to between 3% and 8% of a brewery's general budget, depending on brewery size and other variables. Natural gas remains as the fuel of choice at 65 percent in the brewery sector; electricity follows at 24 percent as the number two fuel in the sector. The use of other fuels, such as heavy (bunker) oil and middle distillates is not widespread. Recently, the consumption of electricity seems to show an upward trend. This change, however, appears consistent with other sectors in Canadian manufacturing. (BAC figures.)

In Canada, energy conservation efforts were first confined to individual brewing companies. In 1993, the Canadian Industry Program for Energy Conservation (CIPEC) established the Brewing Sector Task Force, which attempted to coordinate efforts and promote exchanges of information on how to conserve energy, water and other utilities in breweries. As shown above, the Task Force soon started to yield results. (Note: Results were, and still are, skewed due to the influence of large breweries on the averaging process. Inherent inefficiencies of smaller scale operations cause many small breweries to have up to twice the specific energy use relative to output as large breweries.)

$$EnergyIntensity = \frac{EnergyConsumed}{Output}$$

A well-run brewery would use from 8 to 12 kWh electricity, 5 hL water, and 150 MJ fuel energy per hectolitre (hL) of beer produced. To illustrate, one MJ equals the energy content of about one cubic foot of natural gas, or the energy consumed by one 100 Watt bulb burning for almost three hours, or one horsepower electric motor running for about 20 minutes. **150 MJ/hL equals also producing 30 kg CO_2e of GHG emissions!**

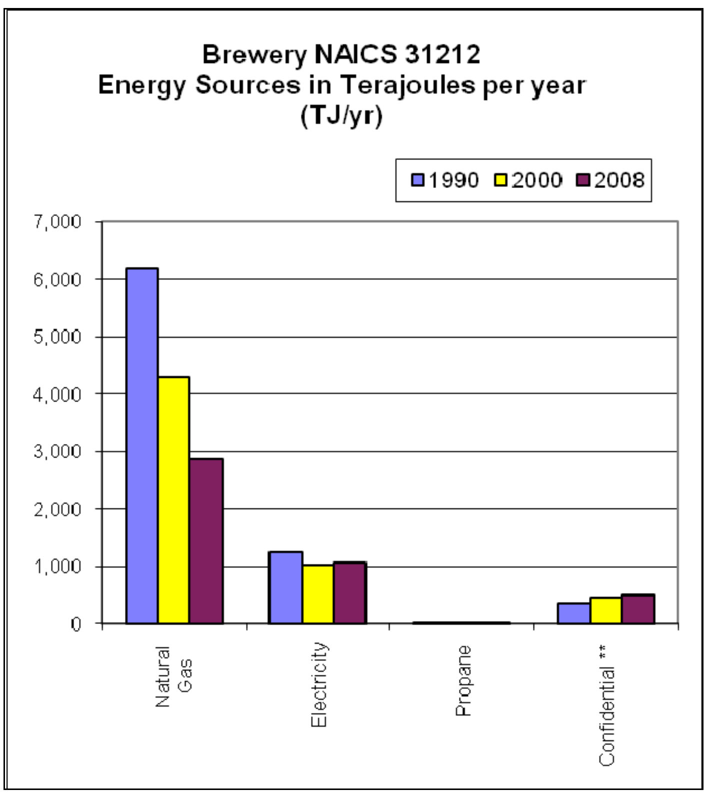


Impressive reductions in energy use have been achieved by the Canadian breweries since 1990. Among the tools to capture this information is the Energy Intensity Index. This is a calculated value that represents how energy intensity changes over time. The current year's energy intensity is compared with the base year of 1990.

Data Sources: Energy Use - Statistics Canada,
Industrial Consumption of Energy Survey, Ottawa. December 2009

Production - Brewers Association of Canada, Ottawa. October 2009.

NAICS = North American industry classification system



The drop in energy use, by fuel type is also revealing (see the chart at left). The "**Confidential category" includes: Heavy Fuel Oil (HFO) and Middle Distillate (Light Fuel Oil - LFO). The drop in natural gas consumption was the main contributor to reducing the Specific Energy Consumption (SEC) from the average **SEC of 346 MJ/hL in 1990 to 187 MJ/hL in 2008** – an impressive achievement!

The focus of this book is to help breweries to reduce their energy and water consumption further. An illustration of what to strive for is given by the most recent (2007) survey of 143 large breweries (>500,000 hL/y), conducted by the U.K. Campden BRI and Dutch KWA. The mean energy consumption was 229 MJ/hL, with the top 10% (decile) at 156 MJ/hL. For example, the pre-merger Anheuser Busch averaged 194; SAB-Miller >150; Asahi and Grupo Modelo both 217 MJ/hL.

Utility management is an ongoing concern in any brewery. Since the primary goal is financial savings, managers must understand the principles of economics and run their department as if it were their own business. Nowadays, competition pressures and narrow profit margins add importance to energy and utilities management. While financial gains from energy efficiency improvements may seem modest compared to the value of sales or to the overall budget, they can contribute considerably to the brewery's net profit. Energy and utilities costs should be viewed as an important part of a brewery's controllable costs. This *"Guide"* should help in the task.

1.2 Brewery processes

There are two or three distinct heating and cooling cycles in the process of making beer. The first one, outside of the scope of this *"Guide",* happens during the drying (called "kilning") of (usually) barley malt – the basic ingredient of beer brewing. In the brewery proper the first heating and cooling cycle happens in the brewhouse in the production of wort (see the description below). The last heating and cooling cycle, often omitted in very small breweries, involves pasteurization of finished product (see further on). The brewing process is energy-intensive and uses large volumes of water.

Malt, made of malting-grade barley – almost exclusively Canadian-grown – is brought to the brewery and stored in silos. From there it is retrieved pneumatically or with the use of conveyors and/or bucket elevators, and is conveyed to the mill room. There, it is crushed into grist of required composition of fines, coarser particles and husks (the husk is the outer envelope of the malt grain). Depending on the technology employed, the crushing is sometimes preceded by steam conditioning of the grain; sometimes wet crushing is employed. In the mash tun, the grist is mixed with warm water ("mashing") and, through a series of heating steps, its starchy content is hydrolyzed and transformed into sweet-tasting wort.

Sweet wort is separated from the spent grains (husks) either by straining in a false-bottomed lauter tun or on frame filters. The residual extract in the spent grains is sparged out with hot water, and the sweet wort is boiled in a kettle with hops and/or hop extracts. During the boil, a certain percentage of wort volume must be evaporated. The resulting bitter-tasting wort is separated from trubs (i.e., coagulated proteins, tannin complexes and coarse insoluble particles from hops and malt) in a whirlpool vessel, employing a teacup principle. Wort is cooled down, usually by passing through a plate heat exchanger (in simpler operations an open cooler may be used) to the required pitching temperature. As well, it is aerated or oxygenated prior to being "pitched" (i.e., inoculated) with contamination-free pitching yeast on its way to a starter tank or a fermenter.

Brewing yeast metabolizes the usable sugars of the wort into alcohol and carbon dioxide (CO_2) and also into new yeast mass. In the fermenter the metabolism releases much heat that has to be removed by chilling. At the end of the fermentation, the resultant green beer is chilled to 0^oC and "racked" (transferred) into the storage tank. The remaining yeast from the fermenter is either used partly for new pitching or is collected as spent yeast for disposal. A part of the yeast still suspended in green beer settles in the storage tank or is removed by centrifuging during the transfer into it. In the storage tank, it is further chilled, depending on its alcohol content, to as low a temperature as possible, usually to $–1.0^oC$ to $–2.0^oC$. After a (flavour) maturation period (called "lagering" or "aging"), the beer is filtered, carbonated and is ready in the packaging cellar for packaging into bottles, cans or kegs. Some types of beers, particularly those produced in small / pub breweries, do not get filtered. The filtration is purely a cosmetic process.

In Canada, virtually all domestic beer bottles are returnable. Therefore, they must be cleaned prior to re-use. Returned bottles make multiple passes through bottle washers (“soakers”) that consist of baths and sprays of a hot caustic soda solution. At the exit, bottles are cooled with sprays and rinses of cold potable water. They then proceed to the filling machine. Cans, always new, are not washed, just rinsed with cold potable water, as are the non-returnable bottles for export. Kegs are cleaned with hot water, caustic solution and steam.

In Canada, bottled and canned beers are usually pasteurized; draught (kegged) beer is usually unpasteurized, just as bottles and cans in small breweries with limited outside sales may not be pasteurized. The pasteurization process takes place primarily in tunnel pasteurizers. It consists of heating the packaged beer to 60^{o}C. Pasteurization kills or inactivates microorganisms that could bring about beer spoilage. Sprays of progressively warmer water bring the beer up to the pasteurization temperature in the holding zone of the pasteurizer. The temperature is maintained for several minutes. Afterwards, sprays of colder water bring it gradually to the usual, rather warm exit temperature of about 30^{o}C.

Packaged beer is stored in a warehouse before distribution. Warm beer, particularly if the oxygen content is higher than it should be, does not keep its flavour well over time; its shelf life is shortened as a result. Therefore, for logistics and flavour reasons, warehousing is brief to avoid the necessity of cooling the warehouse.

2.0 APPROACHING ENERGY MANAGEMENT

2.1 Strategy considerations

All breweries in Canada are faced with ever-increasing competition for the shrinking beer market. Cost reduction has become one of the drivers for successful survival. Savings in energy and utilities costs can help the profitability of any brewery. Many of the energy conservation principles espoused in the first edition of this *"Guide"* has become embedded in the energy management of Canadian breweries. These efforts helped to drive the specific energy consumption down by an impressive 59 MJ/hL.

An ad-hoc approach to energy management is not effective. It usually addresses immediate and/or randomly chosen needs without the benefits of a cohesive, consistent approach. However, out of necessity, given the scarce resources available, it is practiced by some smaller breweries in Canada, but it is not limited to them.

> *Put the energy efficiency into perspective. If your energy budget is $1 million, and you could save just 10% through better energy practices, ask yourself:* ***"How many hectolitres do I have to sell to earn the $100,000 – net?"***

A brewery that is serious about improving the energy and utilities effectiveness needs to adopt a systematic ad consistent approach – <u>that of a system, not just of a program</u>. It starts with development of an energy policy.

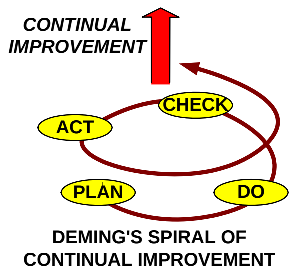
<u>Energy management in a brewery will have two major parts: deployment of management techniques and process improvements</u>.

To start, a few major components must be put in place:

1. Firm commitment of top management
2. Clearly defined program objectives
3. Organizational structure and definition of responsibilities
4. Provision of resources – people and money
5. Measures and tracking procedures
6. Regular progress review

These points are further expanded on in Fig. 1 and in section 2.3 – Defining the program.

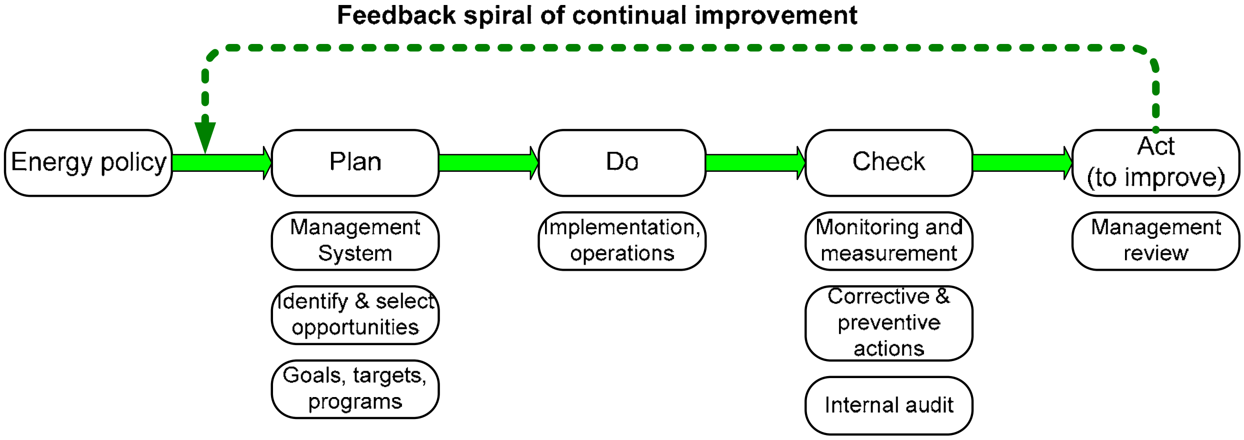
2.2 Useful synergies – systems integration



Shortly after the World War II, an American statistician, Dr. Edward Deming, formulated a principle, which is the basis of any management system in existence today, and is the foundation of continual improvement. It is expressed by the words Plan-Do-Check-Act, as shown in the graphical representation here. Often, the abbreviation PDCA is used.

In a linear view of an energy management system, starting with a policy, these elements include the following main blocks of activities:

Fig. 1.2.1 Linear view of an energy management system



Each of those words represents a logical step on the road to the fulfillment of the requirements and – when those activities are performed well – to reaching an objective – whether it is good process and product quality, protection of the environment, reliable accounting system, well-implemented occupational health and safety, or energy efficiency. Literally hundreds of international standards and guidelines have been generated in the past decades, primarily though the International Organization for Standardization, of Geneva, Switzerland. These standards and guidelines have been produced through the work of international work groups and adopted by individual countries, and bear the prefix ISO (= *"the same"* in old Greek), followed by an assigned number and the year of the latest revision. The ISO standards, of prime interest to brewers, are:

- ISO 9001:2008 – management system for quality;
- ISO 14001:2004 – environmental management system;
- OHSAS 18001:2007 – occupational health and safety assessment system;

and in the context of energy efficiency improvements, discussed here, also the draft of the brand new

- ISO 50001 (DIS) – energy management system.

Among other relevant norms and guidelines are

- HACCP – Hazard Analysis Critical Control Points; and
- ISO 31000:2010 – risk management principles, framework and application.

Standard:	**Description:**
ISO 9001:2008	**Management system for quality.** In breweries as in any other business, the mantra "Satisfy your customer" drives the quest for quality. More and more breweries worldwide have adopted the standard, along with hundreds of thousands of various businesses worldwide, which have embraced the standard since its inception in 1987. In many industries, certification to ISO 9001 has become a requirements and a condition for staying in business.
ISO 14001:2004	**Environmental management system.** The implementation of an environmental management system (EMS) will result in continually improving environmental performance. The specification of the standard is based on the concept that the organization will periodically review and evaluate its EMS to identify opportunities for improvement. Although some improvements in environmental performance can be expected on the basis of the adopted systematic approach of the standard, EMS is primarily a tool that enables an organization to achieve and systematically control the level of performance it sets itself. The organization has the freedom and flexibility to set the boundaries of its EMS. The system's requirements and criteria are also suitable to occupational health and safety and energy efficiency improvement effort.

OHSAS 18001:2007	**Occupational health and safety assessment system.** The standard has been adopted by many countries but has not yet become an international standard. It offers the means to systematically, consistently and proactively manage the workplace hazards with the view of long term goals for ensuring health and safety of all employees. Although much broader in its scope, its structure closely emulates ISO 14001.
ISO 50001 (DIS)	**Energy management system** (document under discussion). In any brewery, energy efficiency enhancement efforts are just one segment in the drive to improve profits, achieve higher quality operations and products, and demonstrably implement responsible environmental behaviour throughout the company. The new energy management system standard enables systematic and consistent approach to the effort. It is a new tool coming at the right time.
HACCP	**Hazard Analysis Critical Control Points.** Since beer is considered a "food", HACCP applies to its production. HACCP, which can also be used as a quality management tool, is a food safety program. It is designed to ensure that at each stage of the production, packaging and distribution processes, any possible hazard that could impact the product and cause it to be contaminated and/or injurious to health have been identified and eliminated. All brewing and packaging materials, brewing and packaging operations, transportation, warehousing and retail operations are scrutinized. From the point of view of energy and utilities, protection from contaminated and/or tainted water, steam, condensate and process gases must be assured. HACCP works with ISO 9001 as a quality management tool. Where more generic, all-encompassing ISO systems have not been put in place, the HACCP system is a quality system in its own right. ISO and HACCP do not have to be run as two separate systems. The Brewers Association of Canada has developed a HACCP program specifically applicable to brewers. Additional information: http://www.brewers.ca/default_e.asp?id=125

ISO 31000:2010	**Risk management principles, framework and application.** The eminently useful standard (explained by Canadian Standards Association norm CSA/Q850-10) is applicable to any situation where hazard exists and risk needs to be assessed (e.g., investment decisions, environmental aspects, occupational health & safety, selection of priorities, etc.) In this context it is interesting to note that Courage Brewery (U.K.) used a dual risk assessment of the hazard occurring with control measures in place at a specified process step compared with the probability of that hazard getting through to the final product with subsequent control measures in place.

Excepting the new ISO 31000:2010, the implementation of all **management systems listed above can be independently audited by accredited bodies** (called "Registrars") **and certified.** The certification – synonymously called "registration" – is the recognition of the compliance to the rigorous requirements of a standard. The certificate becomes a public document.

All of these programs have something in common – the desire to improve quality in the broadest sense of the word. Their systematic, structured, consistent and thought-out approach makes them valuable.

Replace programs with system approach	Programs are limited in time. Often, various programs are initiated and launched in a brewery in isolation from others. Sometimes programs that have not been well planned and/or have not received sufficient support will flounder and die off. "Flavour of the month," employees will say. On the other hand, systems continue to operate indefinitely, using programs to achieve specific goals within the systems. There, programs are made an integral part of the overall improvement strategy.
Take advantage of the systems' compatibility and synergies	The ISO standards listed above are fully compatible. The similar structure of modern management system standards – by now pretty well perfected – enables systems integration in one enterprise-wide management system. For example, the energy management system need not stand alone. Many of its elements can be integrated with those similar in other systems. That is profitable: overall management system becomes streamlined, simpler and activities interwoven, giving rise to valuable synergies and higher effectiveness.

Integration of systems makes company's life easier

Integrating systems that share a common philosophy into an overall management scheme makes sense because doing so offers:

1) Unified management system:
   - Efficient
   - Duplication eliminated or reduced
   - Proactive, predictable, consistent, modifiable, understood
2) Training:
   - Efficiency and effectiveness
   - Conflicting training requirements minimized
   - Multi-disciplined approach
   - All in one program
3) Resources:
   - Best utilization of people, energy, and materials in the context of a single overall management system
4) Improved compliance posture:
   - Increased confidence by regulators
   - Tangible demonstration of commitment
5) Savings on costs of:
   - Materials and labour
   - Energy
   - Product-in-process, finished product
   - Waste
   - Contingency liability costs
   - Public relations and goodwill

Advantages of system registration

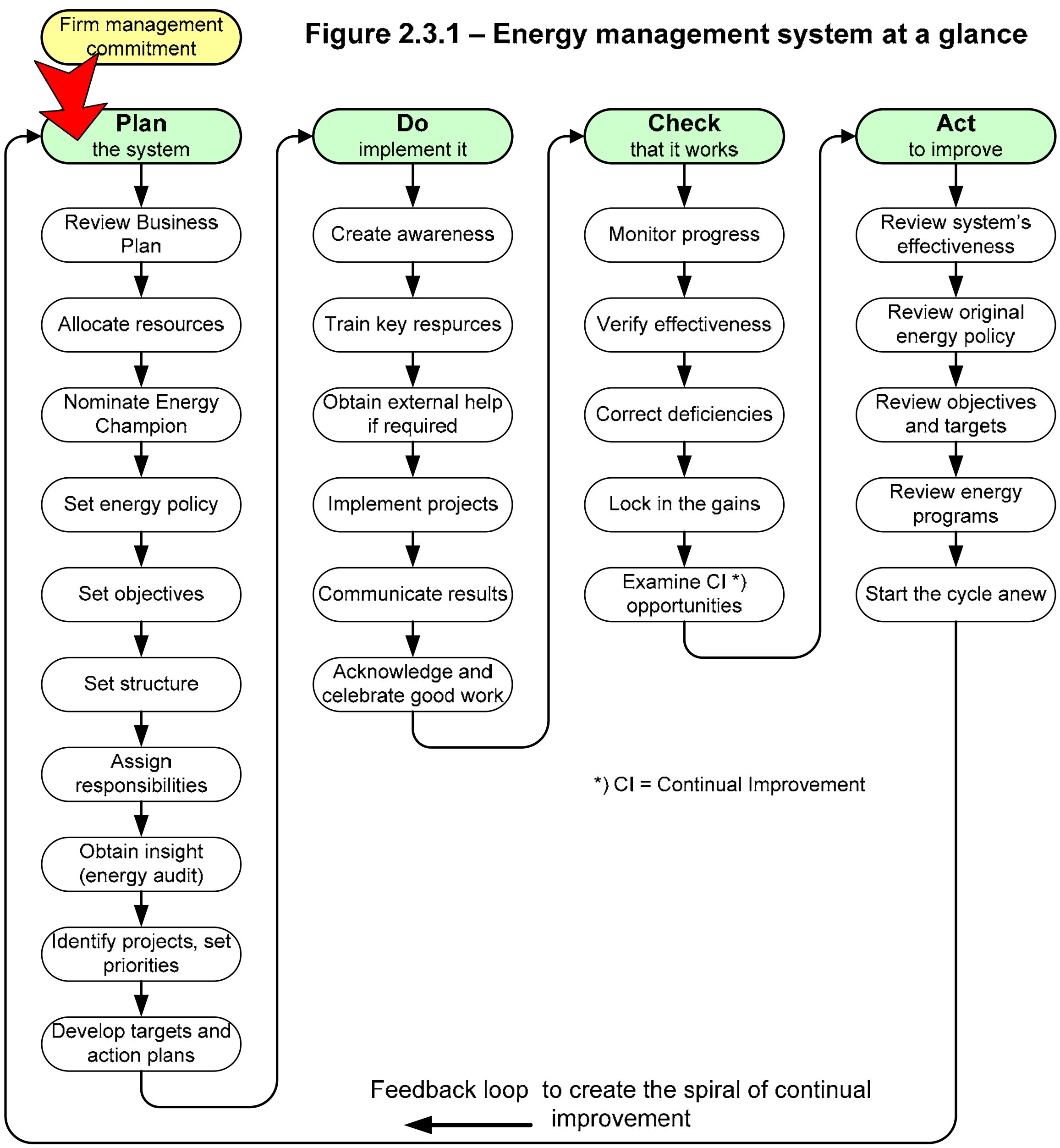
The quantifiable benefits of a management system implementation and subsequent registration can be summarized as follows:

- improved documentation of process procedures and work instructions
- improved communication throughout the organization
- improved product, process or service performance and customer satisfaction
- prevention of errors in all operations
- improved productivity, efficiency and cost reduction
- improved quality of work and employee satisfaction
- public recognition leading to improved market share

2.3 Defining the program

The generic plan of setting up an energy management system is given in Fig. 1. It represents an ideal, proven scenario, where the various steps are approached in a rational, reasoned and systematic manner. The description of the strategy may not fit the resource situation in smaller breweries. Try then to adopt and adapt the steps that lay within your powers.

Figure 2.3.1 – Energy management system at a glance



If you create an energy management <u>system</u> successfully, you will be able to launch successful energy management <u>programs</u> as well.

Top management commitment:

The role of top management is to lead and set the course: a change is initiated from above. The close involvement of top (and middle) management and by their ongoing, visible commitment will demonstrate to everybody that improving energy efficiency in the brewery it is a serious, important matter, worth supporting. It will greatly improve the effectiveness of the energy management system.

Review business plan and allocate resources:

This will provide information about the needed or anticipated impact of energy savings on the profit line as well as the resources required for planning, implementing ad maintaining a viable energy management system.

The effectiveness of an energy management program depends on the time and effort those who are charged with its implementation are allowed to put in. Therefore, adequate operational funding is essential. Without it, and freeing up people to do the work, not much will be done.

Nominate the energy champion:

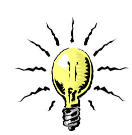
It should be a technically competent person enjoying respect and support of the brewery staff and employees. The champion should be a “doer” – and a good organizer, facilitator and communicator. The champion should demonstrate high levels of enthusiasm and deep conviction about the benefits of the energy efficiency program and be an eloquent advocate of the cause. To enjoy free access to senior management, it should be an executive-level appointment. The function will almost always be an add-on to an existing position, and reallocation and/or sharing of responsibilities may be required.

Set energy policy - create awareness:

Support the launch of the energy management program with a strong policy statement from the brewery’s chief executive to the employees. Develop the energy policy in consideration of other company commitments, policies (quality, production, environment, health and safety, etc.) and strategic goals.

Soon thereafter, start an awareness campaign, utilizing a brief presentation, charts, posters, home mailings, attachments to pay stubs, and other suitable communication means, which should explain the benefits of efficient energy use to the entire brewery. Everybody should be aware also of the broader environmental benefits of energy efficiency improvements – of how the energy conservation will lower emissions of greenhouse gases and help fight the global warming.

An excellent *“Toolkit for Your Industrial Energy Efficiency Awareness Program”* is available from NRCan publications



(E-mail: indust.innov@nrcan.gc.ca).

Decide on objectives:

The objectives the brewery sets should be clearly defined, measurable, challenging yet realistically achievable. They may cover several time horizons – short-term to long-term. They should be communicated to all, and everyone should understand them.

Set structure and assign responsibilities:

The champion chairs the Energy Management Team (EMT) and takes overall personal responsibility for the implementation and success of the program and accountability for its effectiveness. The EMT should include representatives from each major energy-using department, from brewing to packaging and maintenance, and from production operators.

In smaller breweries, all management staff should necessarily have energy consumption reduction duties.

Obtain insight:

Identify projects, set priorities:

Develop targets:

See section 4.0, where these three subjects are treated in a context.

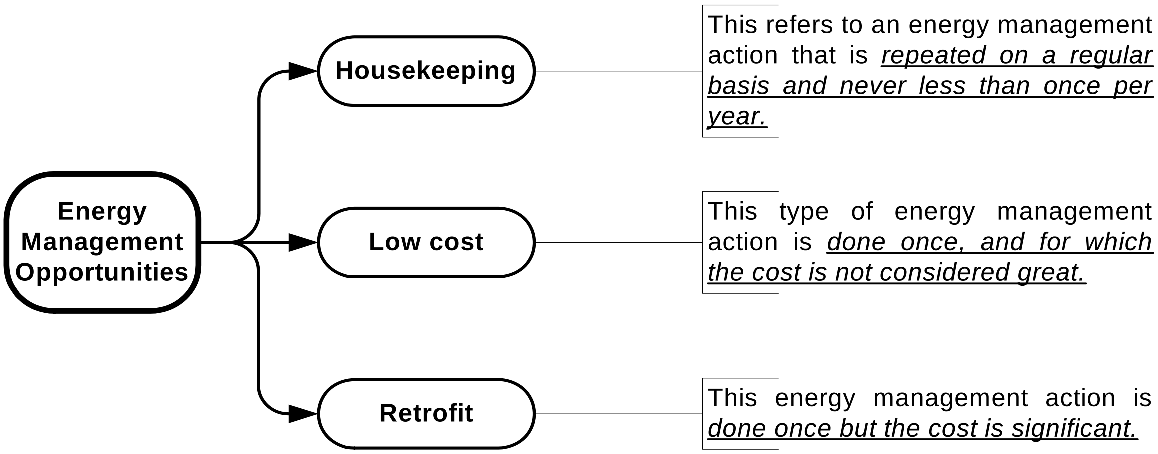
Develop action plans:

An action plan is a road map: a project management and control tool. In it, identify the responsibilities, specific tasks, resources (money, people, training, etc.) and timelines for individual projects and their stages. Several project management software packages are on the market to facilitate the creation of a project plan, for example, Microsoft Project Manager; Gantt charts used to monitor and control project fulfillment, costs, etc.

When selecting energy efficiency projects for implementation, one is looking for **energy management opportunities** (**EMOs**). Typically, we can divide them into three categories:

- Housekeeping
- Low cost
- Retrofit

We shall use this classification in describing the EMOs in section 8.0 – Technical and process considerations, later on.



Train key resources:

Training is expensive and time consuming, yet it pays dividends. It can be organized typically in two stages. The first stage involves specific training for selected employees, i.e., those, who will be involved in the energy management program and/or have a greater influence upon energy consumption than others.

Ideally, the second stage may follow in due course. It consists of integrating energy management training into the existing company training matrix, to ensure that energy training is regularly covered. Generic team training, e.g., in conflict management, problem solving, should also be provided to the EMT members.

> NRCan sponsors a number of specific energy efficiency improvement courses, in collaboration with local colleges and through CIET across Canada. Other sources of training are available through utility companies, etc.; see chapter 2.4 – Accessing external help, further on.

Implement projects:

Consider one project in relation to another – linking them will help to make your program coherent and you will benefit from the projects' synergies. It pays to start with "training" projects that yield maybe only modest but quickly obtainable savings, especially projects to correct the obvious sources of waste found in the initial energy audit. The early successes will encourage the team to tackle bigger projects and seek greater savings. With growing confidence, they will address areas of less obvious energy consumption, such as energy used in heating and ventilation of the packaging hall.

> *Take advantage of various projects' synergies for even greater energy savings.*

Communicate the results:

The progress of an energy conservation project and the results it has been bringing should be communicated to the entire brewery. Ensure the communication is brief and preferably visual (charts, signs, pictograms, etc.). Talk about it at plant meetings.

Acknowledge and celebrate good work - celebrate the success:

This is often an overlooked yet a very important segment of a program. People crave and value recognition. A myriad of ways can be employed to recognize the achievement and highlight the contribution of teams (rather than individuals – that can be divisive!): giveaways of thematic T-shirts, hats, and other merchandise, dinners, picnics, company-sponsored attendance at sporting events, cruises – there is no end to it. The achievement of a target should be celebrated as a milestone on the way to continual improvement of energy efficiency in the brewery. The results may not be definitive yet, but it is the effort that went into a project that is being acknowledged, unconditionally!

Monitor progress:

As with any project, the progress in its realization should be monitored, results measured against targets, and reported at management meetings. This ensures that the project remains viable and gets the attention needed to prod it along.

Verify effectiveness:

If a technical solution was implemented in a project, the verification of effectiveness may be as simple as ongoing monitoring of performance. When the project involves behavioural change (e.g., turning off idle equipment), the verification of the effectiveness of the measures taken should take place after some time has passed (e.g., a month or two).

Has the project lived up to the expectations? Is the implemented energy efficiency improvement effective? Is it being maintained? To support the credibility of energy management efforts, the effectiveness of measures taken must be verified, so adjustments can be made and future projects managed better.

Correct deficiencies:

This is an obvious step to take when performance is not what has been expected. The plant may use an ad-hoc approach, or – if they have a formalized quality or environmental system in place – a defined way for addressing corrective actions. In it, the determination of the systemic root cause of a deficiency is a most important task, followed by proper application of corrective measures.

Information gained from the monitoring of data, from the input from EMC and others, from the review of results and from the verification of the project's effectiveness may indicate that a corrective action is required. The energy management champion is responsible to arrange the corrective action with the EMT team and the personnel from

Correct deficiencies: (Continued)

the respective area involved. The root cause of the deficiency will be determined and the required corrective action will be initiated. Future energy efficiency projects will benefit from the lessons learned.

(Do remember to document it, as necessary. This keeps track of things and the history serves as a learning tool for avoiding shortcomings in other projects.)

Lock in the gains:

The above two steps are what is needed to make the improvement last. Ideally, the solution implemented should produce ongoing benefits.

Examine continual improvement opportunities:

Look for chances to implement the specific energy conservation measure in other areas – where the need for it may have been overlooked conditions are similar. This ‘feed forward’ mechanism amounts, in fact, to a preventive action.

> *Looking for other opportunities is the essence of **continual improvement**, which should be promoted in the self-interest of any organization.*

Often one project opens the door to another idea. The energy efficiency improvement program is an ongoing effort. The EMT and all employees should be encouraged to examine and re-examine other opportunities for further gains as a matter of course, on an ongoing basis. In some companies, this is a permanent item on the agenda of EMT meetings.

Review (energy management) system’s effectiveness:

In order to keep the energy management issue alive and to sustain interest, regular reporting on the effectiveness of the system to the management team is necessary. The energy management updates should be a permanent agenda item of regular operations management review meetings just as quality, production, financial and environmental matters are. Results of implemented projects are reviewed, adjustments are made, conflicts are resolved, financial considerations and resource needs are taken into account.

Review energy policies, objectives and targets, energy efficiency improvement programs and action plans:

This step ensures the continued relevancy and currency of the energy policy. Supporting it are objectives and targets. As they change in time, their review is required to ensure that priorities are maintained in view of present conditions. Yearly or semi-annual review is probably the best frequency for this task.

<u>Review energy policies, objectives and targets, energy efficiency improvement programs and action plans</u>: Continued

The energy efficiency improvement program and action plans are “living” documents. Their updating and frequent revisions are necessary as old projects are implemented and new ones are initiated, and as business conditions change. The energy management champion leads this activity. She/he needs to get input from the EMC and others and subsequently seeks an approval of the updates from the management team.

The feedback from the reviews is used in the new cycle of the activities.

2.4 Accessing external help

The following is a brief listing of only some resources available at the time of this publication (summer 2010). As programs may have a limited "shelf life" given by budgets and political considerations, please do check on the current programs with NRCan and its Office of Energy Efficiency, and appropriate federal Departments and provincial Ministries, and utilities.

2.4.1 Federal government activities

Natural Resources Canada (NRCan), and its Office of Energy Efficiency (OEE) are the hub of all energy-related matters in Canada. (http://nrcan-rncan.gc.ca) and (http://oee.nrcan-rncan.gc.ca)

Financial Assistance for Industry:

ecoENERGY Retrofit Incentive
Find out about funding for small- and medium-sized companies to undertake energy-saving projects.

ecoENERGY Assessment Incentives
Find out how to defray the cost of hiring a qualified consultant to conduct a process integration study and/or computational fluid dynamics study.

Tax Incentives
Take advantage of tax incentives for investments in mechanical systems that generate electricity and/or produce heat.

Renewable Energy
The ecoENERGY Renewable Initiative funds renewable heat and power projects.

Research and Development
Visit the CANMET Energy Technology Centre Web site to learn about funding for the development and promotion of new technologies.

Innovative Financing Approaches
Discover innovative and creative ways to finance large energy efficiency projects.

Transportation
Learn about FleetSmart rebates that can help you manage your fleets more efficiently.

Directory of Energy Efficiency Programs for Industry
Find energy efficiency and alternative energy programs of specific interest to Canadian industry.

Training and Awareness for Industry:

Perhaps the longest running and the most popular is the series **"**Dollars to $ense Workshops" (*Dollarsto$enseWorkshops@NRCan.gc.ca*). They teach participants how to better plan, monitor and reduce their company's energy consumption. The definite schedule for fall 2010 will be published when this "Guide" will go to print, but **"**Dollars to $ense Workshops" series is expected to contain these modules:

- Energy management planning
- Spot the energy savings opportunities
- Energy monitoring
- Energy efficiency financing

Other training programs and workshops are also available:

- Employee Awareness Program
  Designed to make everyone in your organization aware of how small every day actions can significantly reduce energy waste, decrease operating costs and increase competitiveness.

- Transportation Workshops
  Participation in SmartDriver training and fuel efficiency workshops could dramatically improve efficiency and reduce the fuel consumption of your vehicle's fleet.

- Training and Workshops for New Industrial Facilities
  Essential training to maximize potential savings when designing and building a new, energy-efficient industrial facility.

OEE's Industrial Energy Efficient Equipment:

Valuable information to assist in the selection and purchase of energy efficient products for your industrial facilities:

- Arc Welding
- Battery Chargers
- List of models: Large Air Conditioners – 19 kW (65 000 Btu/h) to 70 kW (240 000 Btu/h)
- List of models: Large Heat Pumps – 19 kW (65 000 Btu/h) to 70 kW (240 000 Btu/h)
- List of models: Packaged Terminal Air Conditioners
- List of models: Packaged Terminal Heat Pumps
- Boilers and Steam Distribution Systems

OEE's Industrial Energy Efficient Equipment: *(Continued)*

- Compressed Air
- Electric Motors
- Heating, Ventilation and Air-Conditioning (HVAC)
- Lighting Products
  - List of models: Fluorescent Lamp Ballasts
  - List of models: General Service Fluorescent Lamps
  - High Bay Lighting
  - High-Intensity Discharge (HID) Lighting Systems
  - Pulse-Start Metal Halide Lighting
  - Traffic Signals
  - Exit Signs
- Pumps
- Transformers
- Uninterruptible Power Supplies (UPS)
- Variable Frequency Drives (VFD)
  - VFD Video
- Other Energy Efficient Equipment

The OEE offers information to assist you in selecting the most energy efficient equipment for other areas of your business – such as office space and warehouses.

OEE's technical information for industry (all web-based also, on *http://oee.nrcan-rncan.gc.ca*) is available on these modules:

Benchmarking and Best Practices
Newsletters, Case Studies and Technical Guides
Energy-Efficient Equipment
Technical Forum
Tools and Calculators
Research and Development
Industrial Systems Optimization
Energy Use Data and Analysis
Energy Management Services Directory
Directory of Energy Efficiency Programs for Industry

Other Grants and Incentives

CIPEC energy guide for equipment and HVAC (inc. heat pumps) for industry
Energy efficiency regulations
Energy Star program

Future fuels program Information about financial assistance in the realization of energy-related projects can be found at
http://oee.nrcan.gc.ca/industrial/financial-assistance/retrofit/how-to-apply.cfm?attr=24

2.4.2 Provincial and Territorial activities

Assistance to industry and individuals is also offered on provincial and territorial basis. The following is a brief selected listing of what is offered (summer 2010). As mentioned before, please do check on the current availability of programs.

In addition to the grants available through the OEE, selected provincial, territorial and municipal entities also offer grants and incentives to help Canadians invest in energy and pollution-saving upgrades.

NRCan website link to provincial /territorial energy programs:
http://oee.nrcan.gc.ca/corporate/incentives.cfm#Alberta

Alberta

- Government of Alberta (administered by Climate Change Central)

British Columbia

- City of Victoria Incentive
- Hydro Power Smart ENERGY STAR
- Hydro's Power Smart Program
- LiveSmart BC: Efficiency Incentive Program

Manitoba

- Commercial Refrigeration Application with Manitoba Hydro

New Brunswick

- Efficiency program www.efficiencynb.ca/enb/home.jsp

Newfoundland and Labrador

- takeCHARGE Energy Savers Rebates
- Newfoundland and Labrador EnerGuide for Houses Program

Northwest Territories

- Arctic Energy Alliance

Nova Scotia

- Government of Nova Scotia Energy Rebate
- Nova Scotia's Department of Energy
- Nova Scotia Power - Energy Savings

Ontario

- BOMA Conservation and Demand Management Program in Toronto
- Clean Air Foundations' CoolShops program
- Government of Ontario solar energy systems rebate program

Ontario (Continued)

- Government of Ontario wind, micro hydro-electric and geothermal energy systems rebate
- Ontario Power Authority
- Power Stream Data Centre Incentive Program

Prince Edward Island

- Office of Energy Efficiency

Quebec

- ENERGY STAR Programmable Electronic thermostat
- ENERGY STAR qualified compact fluorescent bulbs
- ENERGY STAR qualified lighting fixtures
- Gazifiere

Saskatchewan

- Commercial boiler program *www.saskenergy.com/business/commercialboiler.asp*

Yukon

- The Yukon Government's Good Energy Program

2.4.3 Other sources of assistance

The internet is an inexhaustible source of information. Among what one can find in it are the following:

- BC Hydro’s Power Smart Medium Industry Programs
- Terasen Gas Commercial
- Enbridge Gas Distribution
- Siemens (Energy Health Check program)
- EnVINTA (One2Five energy diagnostics, other tools)
- Union Gas
- Seneca College in Ontario offers some energy –related courses as well. Recognition is available through college certification, the Energy Training Ontario Registry and the Canada-wide Inter-Provincial Facility Training Accreditation Council (IFTAC/CAIFE).

Virtual library of energy-related literature, brochures and pamphlets is available through *http://oee.nrcan.gc.ca/publications/infosource/home/index.cfm*

2.4.4 Tools for self-assessment

Some tools and programs have been mentioned above. However, there are some other sources of help when you want to perform a self-assessment. Here are some of them:

Steam system assessment tool:

Downloadable software package to evaluate energy efficiency improvement project for steam systems. It includes an economic analysis capability. Contact: U.S. Department of Energy, Office of Industrial Technologies. *http://www.oit.doe.gov/bestpractices/steam/ssat.html*

Steam system scoping tool:

Downloadable software package. Spreadsheet tool identify energy efficiency opportunities in industrial steam systems. It includes an economic analysis capability. Contact: U.S. Department of Energy, Office of Industrial Technologies. *http://www.oit.doe.gov/bestpractices/steam/docs/steamtool.xls*

Optimization of the insulation of boiler steam lines:

Downloadable software package to determine whether boiler systems can be optimized through the insulation of boiler steam lines. The program calculates the most economical thickness of industrial insulation for a variety of operating condition. It makes calculations using thermal performance relationships of generic insulation materials included in the software. Contact: U.S. Department of Energy, Office of Industrial Technologies. *http://www.oit.doe.gov/bestpractices/software_tools.shtml*

Pump system assessment tool:

Downloadable software package to help industrial users assess the efficiency of pumping system operations. PSAT Uses achievable pump performance form Hydraulic Institute standards and motor performance data from the MotorMaster$^+$ database to calculate potential energy and associated cost savings. Contact: U.S. Department of Energy, Office of Industrial Technologies. *http://public.ornl.gov/psat/*

MotorMaster$^+$:

Downloadable software package for energy efficiency motor selection and management, including a catalog of over 20,000 AC motors. It contains motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting and environmental reporting capabilities. Contact: U.S. Department of Energy, Office of Industrial Technologies.

http://www1.eere.energy.gov/industry/bestpractices/software_motormaster.html

AirMaster^{+}:

Downloadable software package as a tool that maximizes the energy efficiency and performance of compressed air systems through improved operations and maintenance practices. Contact: U.S. Department of Energy, Office of Industrial Technologies. http://www.compressedairchallenge.org/toolbox/index.html

ENERGY STAR Portfolio Manager:

On-line software tool that helps assess energy performance of buildings by providing a 1 – 100 ranking of a building's energy performance relative to national building market. Measure energy consumption forms the basis of ranking of performance. Contact: U.S. Environmental Protection Agency. *http://www.energystar.gov/index.cfm?c=business.bus_index*

Insulation calculator tool:

See 3E Plus Insulation thickness calculator at *www.pipeinsulation.org*

3.0 ENERGY AUDITING

A question maybe asked: why have an energy audit[1]? Can't an excellent energy conservation project, yielding good financial return, be undertaken without an audit?

Yes, it can. It is likely, though, that without the systematic approach of the audit, this ad-hoc application of energy management may cause many – (some even better) – opportunities to be missed, thus the benefits of projects' synergies would remain hidden.

Let us describe how an energy audit could be formally organized, executed and its results used. While that way may not be followed – especially in modest circumstances of smaller breweries – its description may, nevertheless, be useful.

3.1 Energy audit purpose

We shall focus on the **initial energy audit**. An energy audit is a key step, which establishes the baseline from which you will measure future energy efficiency improvements. (Other energy audits may be performed later, for example to verify achievements or uncover other incremental energy saving opportunities.)

Clearly then, the purpose of an energy audit is to establish and evaluate energy consumption in a brewery, and, at the same time, uncover opportunities for energy savings, i.e., for improvements of energy efficiency. For the audit to have the maximum value, it should address and express in quantified ways:

- Examination and evaluation of the energy efficiency of all energy-consuming systems, processes and equipment (including energy supply and the building envelope)
- Indication of process management inefficiencies with negative impact on energy consumption

Presented below, is a list of practice-proven steps in energy auditing.

[1] ISO 14001 defines an audit as "a systematic, documented verification of objectively obtaining and evaluating audit evidence, in conformance with audit criteria and followed by communication of results to the client."

3.2 Energy audit stages

3.2.1 Audit initiation and preparation:

Define the audit scope:

The scope of the audit is established by the brewery's management.

What is to be achieved? The determination of accurate energy consumption baseline? The quantification of thermal energy losses only? Will the determination of electrical energy, gas, water, steam and material balances be required? An indication of opportunities for improvements? All of these?

It may help to visualize the audit boundary as a "black box" enclosing the audit area, and then to focus on the energy streams flowing into and out of the box, and examine what happens to them within the box. The "black box" can be the entire brewery or a particular operation, e.g., brewing.

Other practical considerations in setting the energy audit scope include: the brewery's staff size, staff's capability and availability, outside consultant's capability, money and time available. Securing resources and collaboration of the brewery's personnel is essential. Do not attempt to stretch the audit scope beyond what is reasonable to accomplish. Wherever possible start small: one bite at a time. Trying to cover too many facilities/processes with a limited number of resources will affect the effectiveness of the audit and its results.

The audit scope describes the organizational and physical extent and boundaries of the audit activities, as well as the manner of reporting. Is the entire facility to be audited, or only a part of it? If the latter, which processes will be used?

The key requirements of the audit objective(s) and scope should be thought through very carefully. They determine the breadth and depth of the audit, (it means the level of detail required for the breakdown of energy use) and the physical coverage of the audit. They also determine the manpower requirements (i.e., costs) for the audit's execution.

Selecting auditors:

The audit process and its results must be credible.

The determination of the audit scope and objectives will give you an idea of the duration of the audit, hence how many people you will need and for how long. For smaller operations, all you will need is a competent individual with suitable technical training and good overall knowledge of the brewery's operations, auditing process and techniques, and particularly that of an energy audit. It helps if the person likes to work with computers.

The selection of an auditor (auditors), then, is all-important. Choose people who are available and have the skills required for what is needed. The person should be objective, of high personal integrity and sound judgment – and be perceived as such! In addition, the auditor should be an effective communicator and be able to relate to people easily. The auditor will get much of the information in personal interviews and discussions with the brewery operators and staff. To gain the necessary cooperation, the auditor's ability to establish a good rapport with employees is essential.

Is there such person in-house? Alternatively, is it necessary to get outside help and hire an experienced energy consultant to do the audit? Often, a company looks at the cost as the major determinant of which way to choose.

Consider the pros and cons: On the surface, the cost of brewery staff help will be considerably less costly than what a consultant would charge. It is possible that the audit would interfere with some of the routine work of the brewery staff, who would participate in the audit.

A learning curve will inevitably be involved. Errors may be committed. For brewery staff, the overall time requirement would be significantly more, possibly twice as much as a consultant would require. The staff may also be biased. They may have become oblivious to certain aspects of their operations. They may not have the broader experience, which facilitates knowledge transfer from other or similar situations, and which a consultant would probably have. – You will have to consider all that.

Budget and audit duration estimation:

Consider the physical extent of the audit and review the objectives in trying to determine the complexity of the audit, and the time and resources it will require. Include the time to prepare for the audit (planning, getting the tools, gathering the required information) and then to evaluate and analyze the results, come up with recommendations and prepare the audit report. Estimate the budget in person-days or person-weeks.

Timing of the audit:

> *Plan and conduct the energy audit with the intent to determine energy inefficiencies in the brewery processes as well as energy losses in the "waste" streams.*

The brewery management must be consulted on this important consideration. You will want the audit to reflect optimum operating conditions at or near production capacity level, so that the data collected over the audit period will give you a true picture of the energy efficiency usage in the brewery operating at its peak. Lower production levels will result in wasting energy.

A period of one to three week's duration, when the brewery is operating smoothly should be selected. This should result in good averages of energy data collected, ideally free of distortions caused by abnormal operating conditions in various brewery departments.

Often, when longer data collection periods are chosen, process abnormalities, interruptions, etc., are bound to happen, which would result in proportionately greater data distortions and higher specific energy consumption.

Determine the production baseline:

Let us suppose that you will be able to collect data over the highest production period. The brewery will operate at some average level below that for the rest of the year. The average production rate, divided by the maximum production capacity will produce the nominal production efficiency, expressed in percent. It is useful to relate the energy consumption to that basis.

Among other things, you will want to use the audit results to establish energy consumption levels based on average production. Typically, this information is not normally available in most breweries. It would facilitate the energy management later on with regards to, for example, setting energy consumption targets, quantification of eventual energy savings, budgeting, capital expenditures planning as well as help in setting true current costs per production unit (e.g., hectolitre, hL).

Gathering available information:

In planning effective use of the audit time, evaluate the existing information to identify and focus on the major end users of energy.

Historical statistics, such as cost of fuels and electricity (annually and monthly), purchase of raw material, supplies, production data, shrinkage and labour data, should be relatively easy to get in most brewery operations. You will need this information when verifying or calculating the material and energy balances.

Getting the tools:

Just prior to starting the energy audit, do check the essentials. Ensure that the contacts on power bars are tightened; that there are no hot spots and excessive heat on the leads and that they are of proper length as specified by the equipment manufacturer; that equipment is not run on two phases only; that switches are cleaned; that phase reversals have not occurred on (wrongly) installed motors, equipment, etc.

It is agreed that the collected data should be accurate to the maximum extent possible. The main meters on incoming natural gas lines, electric power supplies and water mains are usually maintained and calibrated by the respective utilities and are expected to produce accurate readings. Likewise, important measurements, e.g., MCC (motor control centre) power meters or demand meters, are usually accurate and can be accepted as such, at least initially. Beyond that, the accuracy of other brewery data is usually questionable and not easy to assess.

Current experience shows that there are too few meters used elsewhere in a typical Canadian brewery. If there were additional monitoring and measuring instruments available, the first thing would be to identify and check them. This review involves checking the calibration and maintenance logs, how their specifications are matching the applications, checking the temperature and pressure compensations, and their proper installation. When there is insufficient time to accomplish all these things before the audit, the identified deficiencies should be noted down for action later on.

It is also helpful to obtain the facility layout diagram, process flowchart, power, water, and natural gas distribution diagrams. Other audit tools that may be employed to prepare and analyze data range from hand calculations used for simple crosschecks, and spreadsheets used for data analysis to simulation programs. Software packages to evaluate the audit data, perform simulations and find optimum solutions are on the market; to get them, a utility company and a number of other sources may be accessed.

Electric power consumed by major equipment needs to be measured. A brewery may consider it useful to purchase an energy analyzer for its ongoing energy program (complemented by a phase analyzer, which is necessary in order to see properly the sinus wave). It would require an investment of around $7,000. The analyzers can also be rented or borrowed from an electrical utility. A consultant may have his/her own set.

3.2.2 Audit execution:

Gathering information:

Focus the search for energy efficiency opportunities to where the energy is most expensive – at the point of end use.

While you are measuring and recording energy consumption data, examine also current brewery practices and procedures. Interview workers and staff. Observe how the job is performed. If necessary and feasible, ask for a demonstration. Compare information obtained from different sources; verify its validity. You want to get objective and verifiable information.

Balances:

It is useful in the course of an energy audit to establish energy and material (mass) balances. They serve to account for all energy inputs and outputs (including waste streams), for a given balance type. They serve to crosscheck and reconcile energy data as one of the means to verify the accuracy of the audit observations and support its conclusions. They are useful for evaluation of the impact of brewery development plans and certain types of energy saving projects.

The balances include:

- *Power balance*
- *Natural gas (and/or oil) balance*
- *Steam and condensate balance*
- *Water balance*
- *Material balance (raw material to saleable beer – extract losses)*

Etc.

The balances can be undertaken for the entire brewery or partially, limited to key equipment affected (e.g., the brewhouse, usage of compressed air, boiler efficiency, etc.). It is useful to use process flow diagrams and, for factual as well as visual representation, to enter the calculations to the appropriate streams on the flow diagram.

Practical production considerations:

In the course of auditing gas-fired and oil-fired boilers, the auditors may often find that there is a lack of controls for the given burner types. In uncontrolled burning the fuel-air mixture is not optimized, and fuel is wasted either way, whether the mixture is too rich or too lean. In the former case, burner temperatures are frequently excessive.

The audit may point out several ways in which electrical energy is wasted, or why payments for power used are needlessly high. Lack of monitoring and controlling peak demand and power factor may often be highlighted. However, these subjects will be dealt with later on in the guidebook.

Brewing and production patterns and process practices influence greatly the energy efficiency and should be examined during the audit, as well.

The auditor should also pay attention to the process equipment and how it is used, to account for energy losses. For example, assess washers and pasteurizers, conveyors, ventilation, the state of their repair; etc. Wasting energy influences, in the first place of course, the brewery's profit).

3.2.3 Audit report:

Following the conclusion of the audit, it is usual to report in two ways:

- Verbal report at the close of the audit, highlighting the observations and tentative conclusions
- Written report shortly afterwards, once the calculations and verified conclusions have been made available

The audit report will contain typically:

- General information – consisting of descriptions of the objective(s) and scope of the audit; location and time (duration); the personnel and resources used; the brewery operating conditions at the time of the audit; general observations; difficulties encountered in completing the measurements and calculations; comments on accuracy, particularly as it pertains to instruments, their maintenance and other identified work that could increase accuracy; and caveats
- Main body of the report with energy usage data, calculations and balances
- Evaluating conclusions, and
- Recommendations

3.3 Post-audit activities

Understanding the audit results

With the delivery of the audit report, the process of key importance – an energy audit – has been concluded. The diligent and professional work of the energy auditors produced a report with results reflecting that particular slice of time when the audit was conducted. Although not absolute, the results can be extrapolated with reasonable accuracy to the average brewery operating conditions. The management team should review the audit report with this in mind and decide on the course of action to be taken.

Energy audit results may give the brewery very concrete directions regarding energy management.

There will be two likely energy audit outcomes:

- *Establishment of a brewery-wide energy management system and a program*
- *Identification of energy efficiency improvement opportunities, indicated by the audit, for the energy management program to address*

4.0 IDENTIFYING AND PRIORITIZING ENERGY MANAGEMENT (ENERGY SAVING) OPPORTUNITIES (EMOs)

4.1 Identifying energy management opportunities (EMOs)

After some time, a picture starts to emerge about what can be done in a brewery to improve the way it handles energy use. A list of inputs may include:

- Results of the initial energy audit
- Review of literature, including Internet sources
- Information about applicable ideas from other breweries, indeed, from other industries
- Consultations with NRCan's CANMET and Office of Energy Efficiency
- Equipment supplier recommendations
- Consultant's advice
- Fresh look at the way the brewery manages its production and operations
- Ideas and suggestions

It all could result in a very long list of energy management opportunities (**EMO**s). By type, the EMOs fall into these broad categories:

Organizational changes	The influence of the **organizational change**, on energy conservation is often hidden. It involves changes in planning and scheduling production in a way that allows for a partial or across-the-board leveling of energy use, hence its better utilization. The point is to try to achieve a more steady-state production output. Granted, this may be a tall order, but one in which the marketing and sales departments can help production staff a lot.
Process changes	It involves improvements in process equipment and technology that result in reduced energy consumption. The **process change** category will probably be the largest and most capital intensive. The improvements include changes to throughput capacity, improved quality (product characteristics), process controls, but, typically, efficiency of energy utilization has not been the driving reason. This can be used to justify other projects and upgrade activities (e.g., variable speed drives, high efficiency motors).

Boiler energy efficiency and potential fuel substitution	It concerns improvement upgrades to burner systems, monitoring and control of flue gas composition, as well as furnace lining and insulation. It focuses on maximizing the efficiency of use and selecting the best source of energy (e.g., oil or natural gas). Fuel substitution is a consideration dependent on fuel market availability (e.g., natural gas in Québec) and cost long-term prognosis.
Electric power management	It means taking measures resulting in reduced electricity consumption, including peak demand & power factor management, and cogeneration. The **electrical power management** is an area which can improve the profit of the brewery quite significantly as well as by comprehensive monitoring and control of electrical energy consumption in general (see Monitoring & Targeting methodology).
Heat recovery	Heat recovery includes projects that are best viewed in the context of the entire brewery; several energy systems may be involved, and synergies are possible to achieve. It concerns the reuse of waste heat streams and their integration and prevention of heat losses in all forms (e.g., heat exchanger, insulation).

4.2 Evaluating and calculating energy savings and other impacts of EMOs

The energy savings of the identified EMOs should now be evaluated. A simple quantification of the differences in energy inputs between the present and the improved states – expressed both in kWh (or MJ) and dollars, on an annualized basis – will do.

The information requires inclusion of capital (and/or operating) costs for modifications/ improvements, and calculation of rate of return on capital invested (ROI). Other implications (benefits/drawbacks) of the improvement project should also be captured in a quantified way, whenever possible (e.g., improvement of production capacity by 15%, consumption of compressed air reduced by 20% or $xx /year).

Remember that the purpose of the evaluation is to do a preliminary ranking of the projects for further selection. While attempting to use reasonably close estimates, do not expend too much effort in trying to achieve four-decimal accuracy of the outcomes at this stage – the correctness of inputs is more important.

To organize all this information into a long list of projects, a table can be constructed as shown below (Table 4.2.1). The columns are self-explanatory, except the Benefits-Cost, where annual energy saved per investment dollar is stated.

Table 4.2.1: Long list of EMO projects (example)

EMO project description	EMO #	Type	Invest. capital $1,000s	Energy savings GJ/y	Benefits-Costs GJ/y/$	ROI years	Other implications of the project
E.g.: pasteurizer optimization	35	Ops	50	150,000	3	3.0	Output up 5%; heat reuse in pre-heating; resize piping; water savings 15%
Etc.							

4.3 Selecting and prioritizing EMO projects

At the first glance, the projects, which offer the highest return on investment, should be chosen for realization. It is not that simple. Other considerations should be made. Project selection and prioritization is often perceived as a very difficult task. The following is a brief guide, which includes some **proven decision-making tools** to make the task simple enough for anyone to do. They include:

4.3.1 Initial scrutiny:

The initial long list of EMO projects is now to be scrutinized from several viewpoints. In addition to clearly impractical ideas, which can be rejected out of hand, the projects not meeting our criteria (very much of our own making, brewery-specific) shall also be discarded. We shall examine:

Technical feasibility

Evaluate all available information, such as:

- Good engineering practice
- Experience of others, testimonials
- Supplier information
- Literature
- Consultants
- Technical uncertainties
- Performance risks

Possible synergies

Can the project be integrated with an advantage with others to achieve heightened benefits (e.g., an upgrade of pasteurizer heat recovery together with improved space heating and ventilation)?

If so, try to quantify the benefits of the projects interaction, and compare this to benefits of the individual projects and their sum.

Possible synergies (Continued)

Consider various combinations of projects before settling for an optimum group to implement jointly. *

(*Note: *The approach described here is considered proper, because it is comprehensive. However, it is recognized that lack of necessary resources may force a brewery to implement a project without the time and effort required in comparing it to others. Once a project is seen as meeting the energy savings requirements, and clears all the other investment hurdles, there is no reason for delaying it. The advantage of this ad-hoc approach is in rapid implementation of projects, which start providing ongoing energy savings fast.*)

Business risks

See the section **4.4.2 Risk assessment**, below, for details.

Business plan and priorities

Consider also the brewery's business plan (usually over several time horizons – short-, mid- and long-term), business priority objectives, and financial situation.

> **"The key is not to prioritize what is on your schedule, but to schedule your priorities!"**
>
> *Steven Covey*

Apply the "**first things first**" rule: put emphasis on a proactive, preventive approach to issues and projects, which will allow departure from the all-too-common firefighting, the crisis management mode of operations. In other words, ask the question: "Is this the right thing to do"?

Project's profitability

1. Assess the total capital cost the project, including, for example:
   - Equipment price, modification, installation, certification
   - Installation space
2. Estimate the cumulative annual operating savings of the improvement project, such as:
   - Power, water, natural gas, compressed air, consumables
   - Maintenance, spare parts, labour

Project's profitability
(Continued)

- Of these, for energy conservation projects, the energy consumption is the most important. (Note that compressed air, due to the high cost of energy involved in its generation, is considered separately.)

3. Calculate the simple payback on investment and express it in years (months, if less than one year).

Do you calculate the return on capital investment only as a simple payback? That is customary, but often it is better to use net present value, or internal rate of return, which is based on projected, discounted cash flow. It is better, because you can include the effect of capital cost allowances (CCA). The CCA vary with the type of assets under consideration. For example, the CCA on machinery is 20% and on buildings 5%. These calculations will show the rate of return more accurately.

4.3.2 Risk assessment

All projects involve risk to some degree. Organizations face a wide range of risks, e.g.:

- **Financial** – Accounting and audit, insurability, credit, insolvency
- **Organizational** – Corporate image, human relations
- **External** – Market, social change, climate change
- **Regulatory** – Regulations, governmental policies
- **Legal** – Legislation, statutes, torts, contracts
- **Operational** – Production, environment, health & safety, assets

Business risk is a threat that an event, action or inaction will adversely affect an organization's ability to achieve its business objective and execute its strategies successfully.

Business risk management is a pro-active approach that helps owners and managers to anticipate and respond effectively to risk. Not all business risks can be eliminated.

To assess whether further effort to reduce risk is meaningful, an acceptable **risk tolerance level** must be established.

Further information on business risk assessment can be obtained from reading for example, the *CAN/CSA-Q850-10 Standard*: *Risk management* or from the similar, new *ISO 31000:2010 – Risk management principles, framework and application.*

Balance the perspectives from the point of view of safety, environment, legal & regulatory, business and public image. Assess the risk by using the formula (as per *CAN/CSA-Q850-10 Standard*):

$$R = E \times L \times C$$

Where ***R*** = risk, ***E*** = exposure, ***L*** = likelihood and ***C*** = consequences (the sum of individual consequences in the areas mentioned above, i.e., for example, environment & legal, safety, business impact and public image/company reputation). Use simple but defined criteria, to assign value to the measure of risk in each of these categories (e.g., high, medium, low, negligible.)

1. Assess if there is a potential for risk exposure in both undertaking the project and its abandonment.
2. Determine the tolerable risk level.
3. Include countermeasures in the project design, if possible.

4.3.3 Costing of a project:

Note that for initial screening purposes, "best guess" rough estimates of a project's capital cost are generally sufficient. We are interested in the order of magnitude at this pre-feasibility level, based on a preliminary concept. Include generous allowance for all cost components that should be considered in the project, such as equipment capital costs, installation costs (mechanical, structural, piping and civil engineering, site preparation, existing equipment modifications/removal, electrical, etc.). Make allowance for indirect costs (such as construction management, contractor's overhead, owner's costs, and consultants). Include generous contingency leeway at this stage. We understand that at this stage the anticipated accuracy may be off by 50%. Use the results for initial ranking.

While it is difficult to predict the future, energy savings projects must be assessed in the context of the brewery's future operations; e.g., future increases of production, possible process bottlenecks and anticipated process changes.

As the project selection progresses, the preliminarily selected projects can now be subjected to feasibility estimating, which uses a more formal and better researched project pricing. Budgetary quotations may be obtained from vendors at this stage. All of the project component costs, as above, must now be carried out in more detail.

When we have narrowed our choices to a particular solution, greater accuracy for a formal project approval process is required. It means that detailed engineering of the project, including drawings, schematic electrical, piping and duct diagrams, issuance of formal requests for proposal to multiple vendors, with all project specifications, etc., must be done. The typical relationships and anticipated accuracy levels are shown on Table 3 below.

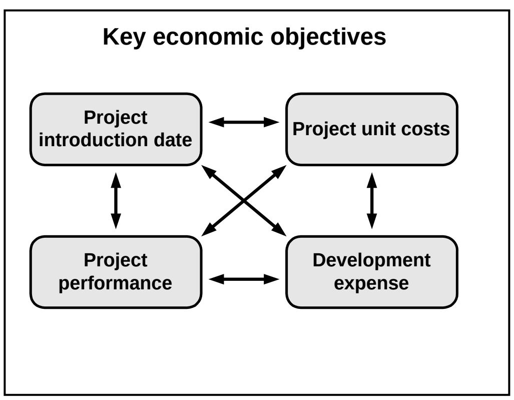
Even then, our task is not quite completed. Before we shall be able to arrive at a more accurate cost of the selected project, we'll have to **examine the possible trade-offs.** We are not living in an ideal word, where all is possible. We must make choices. There are many considerations, each of which has a cost attached to it, and we must find an optimum solution. That optimum solution should then be the subject of project submission approval.

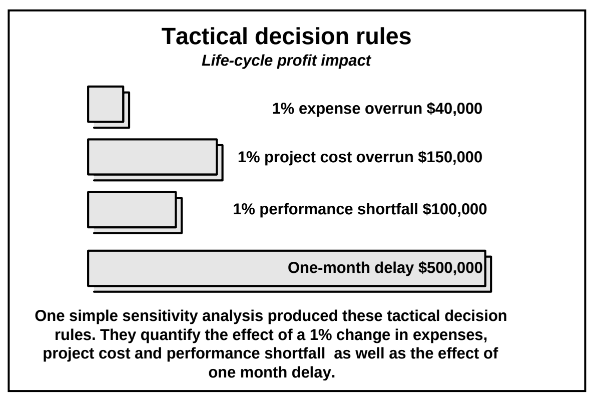
Table 4.3.3.1: Cost estimation accuracy

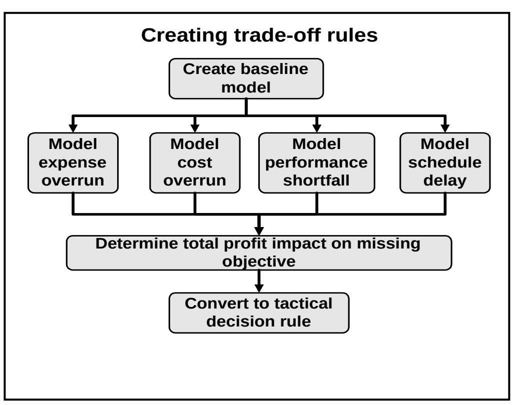
Project stage	Appropriation costs, %	Indirect costs (as % approp. costs)	Contingency cost % of total
Pre-feasibility study	± 40-70	± 30-50	+20
Feasibility study	±25-30	±25-35	+10-15
Project approval	± 10, or 0-10	±20-30	+ 5

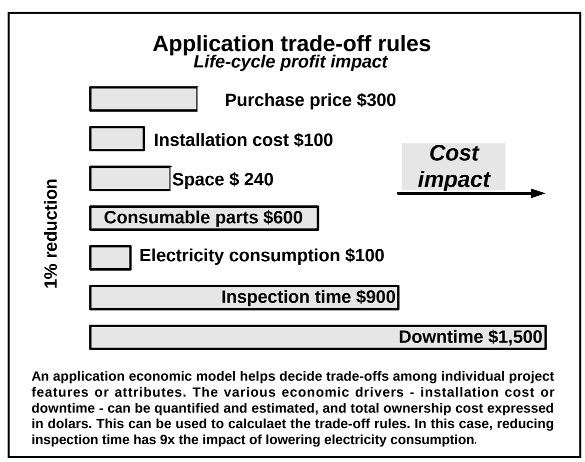
<u>4.3.4 Economic model for trade-offs</u>:

If you deal with a complex project with many variables, you may wish to consider <u>computer modeling (computer simulation)</u>. The advantages are speedy answers to multiple scenarios. The disadvantages include high cost and skill level required to run a computer-modeling program.









Charts after D. Reinertsen, Machine Design, May 1998

For those disinclined to use computer simulation, another proven, very simple economic modeling tool is available, courtesy of Reinertsen & Associates of Redondo Beach, CA (*"Do your product development math", Machine Design, May, 1998)* - above. It is based on setting uncomplicated trade-off rules in project development. It recognizes that every project has four key objectives:

- Schedule – target date
- Project unit cost
- Project performance
- Development costs

Trade-offs between them should maximize a project's profitability. The model allows making the right investment decisions.

The target date is the date when the project should be fully on stream. The product unit costs is the implemented costs expressed based on product unit, one hectolitre, etc. The project performance measures the revenue stream over the projects lifetime from the saving/improved productivity it will achieve. The development expense is the one time cost associated with the development of the project.

The next step is to assign a dollar value to 1% change of each of those parameters. This is brewery-specific, something we can set as a rule-of-thumb very easily. We may now model, for example, a 50% overrun of development (i.e., equipment procurement and installation) expenses, a 10% overrun of production costs, a 10% performance shortfall, and a 6-month delay in project commissioning. By applying the dollar values to each of the parameters, we can quickly see what impact each change will have on the anticipated saving (profit).

The economic model can be applied also to a trade-off between features of the particular equipment, as the table in the lower right-hand corner above shows. For it, the total project ownership costs must be estimated (i.e., equipment cost, installation, commissioning; space cost; power, compressed air, consumables; cleaning, maintenance, labour; cost of breakdowns; spare parts, bad product; cost of downtime; lost production time & volume; cost of missed sales, etc.). Expressed in dollars, the total ownership costs help in deciding trade-off amongst different performance/equipment attributes.

Important note:

The economic model can also be used by a brewery in evaluating product development characteristics and possible trade-offs (i.e., substitute appropriate terms, such as market introduction date, product, etc., for those used in the above and relating to projects).

A few tips on how to implement the economic modeling tool:

- Keep the financial model simple - when input data is imprecise, do not fret over accuracy of product unit costs; use cumulative profit before taxes instead – this is something that is generally understood. Focus any extra effort on making the input data as accurate as possible
- Involve the right people – different team members may have different critical information needed to construct the model; involve the financial controller for analytical as well as political reasons

It requires an effort to make any cultural change – here to ***turn away from intuitive decision-making to rational quantification.***
It is worth it!

- Make the trade-off rules visible – Post the key numbers (e.g., what is one hour of downtime worth, etc.), so people see them all the time and will use them routinely. Review those numbers from time to time
- Use the project economic model for decision-making – be consistent in using it systematically
- Integrate the tactical decision rules in your business process – make the decision rules a part of every project (and for example of, e.g., any new-product business plan, too!). Start every project with a consistently calculated, reviewed set of tactical decision rules
- Don't develop projects (products, etc.) unless you are ready to do the simple math!

4.4 Developing energy management programs further

A successful energy management program in a brewery is more than just a sum of EMO projects. Using all the various inputs we mentioned earlier, one should make ideally a focused effort on preparing a:

Benefits realized from housekeeping projects, requiring no capital, are immediate and significant.

- First-year detailed project plan
- Medium-term energy saving plan for the entire brewery
- Long-term energy saving plan
- Plan to improve energy management in general, including the setting up of an energy monitoring system

This can be tailored to the brewery's circumstances – a very simple sketch for a small brewery as opposed to a detailed one for a large brewery.

The last point involves an education and awareness campaign to improve housekeeping practices. Quite assuredly, as mentioned, these will generate **energy savings of 10-15% just through the elimination of wasteful practices, with no capital investments required.**

Setting priorities

> *Beware that without ongoing attention, the low-hanging fruit may grow back and the initial effort would be wasted!*

Establishing priorities will involve consideration of business needs and some of the decision-making tools described in the previous section. It pays to remember one worn-out but true cliché: ***one has to walk before one can run!*** Start the program with projects that will bring in results quickly and rather easily – harvest the low hanging fruit. That will be a great source of motivation to employees – to see that it can be done and that they are successful. It will give the members of the energy management team the confidence to start more complex and long-term projects. You may want to include in the initial projects those, which will correct the obvious sources of waste found in the initial energy audit.

Self-assessment provides a cue:

In the UK, Campden BRI in collaboration with KWA developed a self-assessment benchmarking tool for energy use in breweries. This enables the user to measure how the brewery performs on energy efficiency compared to other breweries in a group, on both plant level and also on process unit level. It also enables the brewers to identify potential measures for reducing energy uses, the potential savings per process unit and the payback time. All this may help the brewers focus on energy use-reduction work that may have escaped their attention.

5.0 IMPLEMENTING ENERGY EFFICIENCY OPPORTUNITIES

5.1 Involve employees!

The energy management program would achieve little without involving everyone in the brewery – from managers to operators – in it. The change of culture must involve all. Active participation and involvement of all employees in energy conservation measures and efficiency improvements are necessary.

Increase energy awareness	**This is the necessary and very important initial step.**
Stimulate interest	Mount a publicity campaign: use existing means of communication to stimulate interest. (Mail special news bulletins directly to employees' homes, use posters, information sheets and energy efficiency handbooks for all employees - plenty of these can be obtained from different sources)
Form a team	Form a team of volunteers from different departments, and give it a catchy slogan (e.g., The Super Savers, Energy Cost Slashers, Energizer Bunnies, etc.). Launch it with hoopla*!*
Focus on simple things first	Reach for the "low-hanging fruit" to guarantee success at the beginning of a program, and to stimulate participation.
These things come free!	Target first the elimination of wasteful practices – zero in on better "housekeeping". Explain simple good housekeeping methods to keep energy consumption down.
Avoid diluting the effort	To concentrate on one type of energy at a time, three separate items may be run, on natural gas, electricity and compressed air, depending on resources available.
Encourage	Give pats on the back: to encourage, monitor progress and report improvements.
Stick to it	Make the change permanent!

To come up with ideas, suggestion programs may help, as well. They need to be maintained systematically and constantly, though, to yield results on an ongoing basis. Some maintain that it is better to base these programs not on the initiative of individuals, but rather on team work. This minimizes the potential of divisive personal rivalries.

Another solution is to approach the issue of energy efficiency in a brewery as an opportunity for continual improvement, and use any of the number of proven techniques to achieve it: e.g., Quality Circles, Kaizen, Total Quality Management (TQM), etc. Of course, when a management system (as per ISO 9001, ISO 14001, OHSAS 18001 or ISO 50001) is implemented in a brewery, the continual improvement is already embedded in this standard as a key requirement for the entire organization. Energy efficiency improvement programs are often selected by the organization to realize its overall objectives and targets (see the previous section). In one such scenario the team focuses on working on an identified need of the brewery.

Ongoing training also helps. Not every brewery can emulate a program a company in Eastern Ontario devised, which invests two hours of training per employee per week as matter of policy, to stimulate intellectual abilities of its employees. Part of the training deals also with energy efficiency matters.

A case study, to illustrate:

Different approaches may work as well. A brewery decided that to train all of their many employees in recognizing energy waste and to reduce wastage was impractical. Hence, just the middle management was chosen, as they were able to influence energy usage, both directly and by motivating their teams. A training course was designed with outside help (electric utilities, gas companies, NRCan).

It had four two-hour modules, delivered over extended lunch breaks – one module per week, at a cost of $150/person. The course first encouraged the participants to carry out an energy audit of their homes, then to draw parallels to energy use at their workplace. They performed a walk-about energy audit of their own department and involved others. The effort resulted in a 3% reduction of the total energy bill, and a payback of only three weeks.

Before the project, only 10% of the workforce regularly took practical energy saving actions. The percentage increased to 85% after the project.

5.2 Communicate!

Effective communication

Communication between team members and brewery employees at large is essential to sustain the interest in the energy conservation program.

A well-executed communication plan is essential for ensuring that everybody feels that they are part of the energy management effort. Regular reports taken from the monitored data encourage staff by showing them the progress towards their goals.

Show the information prominently on bulletin boards where people can see them. Someone should be in charge of posting and updating it regularly. Old news is not interesting. The format, colours, etc., may be changed from time to time in order to maintain the visual interest of the information.

> *Remember:* ***people do not like reading memos!***
>
> *Use simplified graphical, visual representations of the results – use charts, diagrams, "thermometers" of fulfillment, etc.* ***Relate it to costs!***

Stay away from a dry format of reporting - use a representation that people can understand. For example, express savings in dollars, dollars per employee, or dollars per unit (hL; 1000 of 24-bottle cases of production, etc.). Show it on a cumulative basis; show how it contributes to the company's profit picture.

The energy management champion should share with the EMT members all of the available information about energy use and challenge them to explore ways to conserve energy in their respective areas. Think about using team contests as a tool.

Just as important is to keep the brewery management informed about the activities and progress made. The objective is to obtain agreement and re-establish support from the management group for the energy management system with each report.

6.0 MANAGING ENERGY RESOURCES AND COSTS

6.1 Energy and utilities costs and management

The brewery accountant could be the energy champion's best friend. All that has to be done is to explain to the accountant the concepts behind energy bills (see section 8.3), and show your friend the energy implications of production non-quality on the total operational costs. Both fixed and variable costs may be affected.

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

The accountant's initial knowledge of energy matters may be limited to bill paying – a situation all too common in breweries with little or no energy metering capabilities and equal lack of interest in energy improvement. However, his or her professional interest may be aroused when measures to control energy costs get explained. To develop a set of key energy indicators, essential metering, monitoring and operational controls are required. Seeing the potential of the measurements and the magnitude of costs, the accountant would most certainly support the energy improvement drive and help in preparing cost justifications for acquisition of the meters and the controls it would require. The rest is the work of the energy champion.

> *The ratio of total energy costs to the total of manufacturing costs represents the energy intensity of the brewery operations.*

Here are some of the indicators that every brewery likely has, as the minimum:

- Cost of electricity – total
  - Consumption charge (time of day/week rates & charges)
  - Peak demand charge
  - Power factor penalty (if any)
- Cost of natural gas (or other fuel)
- Cost of water (includes sewer charges)

The energy intensity, the cost of energy per hectolitre, electricity per work hour, and similar global measurements can be developed from these data. It is not always possible to say what the energy costs are for heating and lighting of offices versus the production brewery, or how much energy this or that process system uses. The basic information is not enough for an effective control: one needs to know ***how, where, when and why*** the energy is spent, and how much it costs. For instance, it may be a revelation when it is determined how much energy is wasted in a brewery during the non-production periods and on weekends! That can be achieved with the help of sub-metering of key equipment/operations. Other indicators may thus be developed:

- Energy (gas, oil or electricity) and cost of energy per hectolitre
- Average load factor
- Average power factor
- Boiler thermal conversion efficiency
- Brewhouse energy demand as percentage of the brewery's,
- Compressor electrical costs, etc.

Such measurements can be used for setting standards, against which new energy consumption (cost) targets can be determined (more on this in sections 6.3 and 6.4). Accounting for energy costs should investigate impact of production practices on overall costs and help in determining optimal solutions. Subsequently, management support and capital funds approvals should be much easier to obtain for:

- Process and equipment changes
- Energy loss reduction programs and energy recovery systems

> Full cost accounting, in the energy context, is akin to costing internal shrinkage in the brewery's energy usage.

Management tips:

- Consider developing meaningful energy performance indicators specific to your brewery's needs
- Conduct seminars or awareness sessions for all operators to explain:
  1. The energy costs and the means of their control
  2. The effect of good housekeeping on driving the energy costs down
  3. 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

6.2 Monitoring and measuring consumption and setting targets

Setting energy conservation targets

What you can measure, you can control. What you can control, you can improve.

This presumes the availability of data. It involves establishing a measurement base, to which the improvements can be related. Often, though, one quickly finds out that there is only rudimentary measurement equipment (and consequently minimal data available) in place, particularly in smaller breweries. It is an obstacle, but not impossibility. We can start an energy management program with this, too. As the program picks up steam and shows results, it will be much easier to convince management to invest in more metering equipment, gauges, sensors and controllers. These will allow data to be generated for key energy-consuming equipment.

You may find that you lack essential performance indication, because it has never been measured. Use the results of the energy audit or calculate energy requirements to establish some benchmarks against which to set future targets. Measure your current performance against industry standards (some of which are stated elsewhere in this book).

Targets should be realistic, measurable and verifiable.

Once a target has been met on a sustained basis over a period of several months, it is time to review it. It can become the new standard and a new, progressive target can be set at a new, progressive value. Target setting helps to involve the entire workforce in energy projects by giving them goals to achieve.

The energy champion in the brewery should manage the energy management plan as an ongoing program, and coordinate a number of the energy saving projects together. In that, consider interactions (beneficial or otherwise) between them also: you would not want to see one project's implementation negating the projected savings of another one.

Tracking energy and utilities consumption implies that energy costs and the cost of utilities are viewed **as valuable resources that must be prudently husbanded just like labour and any other variable.**

This can be approached best from the point of its purpose: to manage the consumption to reach an objective, against a set target and past performance, and to react to aberrations from normal with corrective and preventive actions, all in view of continual improvement. The analysis of the performance must take into account other accompanying factors, e.g., percentage of beer shrinkage, or production and process variations.

Selecting proper measurables	Monitoring ad measuring consumption requires careful selection of meaningful measurables that allow comparisons over time, using the same reference – e.g., kWh/hL of beer sold. The selection of the reference point is usually what causes some difficulties. Other bases could be selected, e.g., consumption of a given resource over hours worked, per employee, per hL of beer brewed (ex-brewhouse), per hL of beer in the government cellar, per $1000 gross revenue, etc. However, these bases may change for a variety of reasons from year to year; hence the real improvement (or worsening) may be hard to determine when the value of the bases shifts. Hence, the ability to track performance over time requires a standard reference point.
The units of measure should not fluctuate over time	Like in other business, breweries can chose the consumption figures related to the saleable product, i.e. to the hL of beer sold, as a measurement that is the most comprehensive, encompassing all influences in the brewery. That is valid for steady-state production make-up, relatively unchanging over long periods. When product make-up fluctuates at the dilution/carbonation volumes (i.e., brand volume sales), the brewery may wish to relate the consumption to a suitable production stage upstream (e.g., ex-brewhouse, ex-fermentation).
Set objectives and a targets, and action plans	Consider past performance, business and fiscal objectives, technology options and implications, in setting objectives in energy and utilities management. Those objectives should be in line with the company policy (policies). Setting a target for appearances' sake is counterproductive. A target should aim for continual improvement and thus be challenging, substantial yet achievable and should involve as broad a base of brewery employees at many functions and levels as possible. Responsibilities, accountabilities, resources required and timelines should form a part of an action plan to reach the objectives and targets.
Visualize performance reporting!	Graphical presentation of the tracked values (regardless if it is energy or productivity or overtime) should include at least these parameters: average value for the past year; current target, current monthly performance and a trend line. The chart is a superb visual tool that conveys information powerfully and at a glance. Nevertheless, the chart can be accompanied by a table, where actual figures and variations can be augmented by the expression of costs – all of these on year-to-date (YTD) basis.

Regular review The performance of managing the consumption should be regularly (e.g., monthly) reviewed, analyzed and reported at business management reviews. This process can only be meaningful and effective when it entails controllable action plans to improve unsatisfactory performance.

Re-setting the target The step-wise target-setting in an improving fashion helps the managers to regard energy as a resource that must be managed with equal attention as other process inputs, such as labour and raw materials.

6.3 Implementing, monitoring performance and continually improving

(Look up also related item under section 8.2.1.)

You, as the energy champion, want to be in control. To implement the energy management plan and the various EMOs, it is necessary to work out specific action plans.

Action plans

These will give you the management and control tool you need to achieve your targets effectively and efficiently. In these, you will specify in the necessary detail, who will do what, when, and with what resources. It will be necessary to involve others in the decisions to get their agreement and support. Several project management software programs can be used to create the graphical representation of the action plans easily.

Start the work early

Do not procrastinate. Delays cause the enthusiasm to wane. Hence – start with projects that are simple and will boost the confidence of the team. In the brewery, provide positive reinforcement that helps employees to willingly adopt the new energy-saving practices.

Remember:

A dollar saved goes directly to the bottom line!

Table 6.3.1: Profit increase from energy savings

If the original profit margin is:	*and if a plant's energy cost percentage is:*					
	3%	4%	5%	6%	7%	8%
	and energy costs were reduced by 35%, then the **Profit margin percentage will increase by the percentage below:**					
1%	**104%**	**139%**	**173%**	**208%**	**242%**	**277%**
2%	**51%**	**69%**	**86%**	**103%**	**120%**	**137%**
5%	**20%**	**27%**	**33%**	**40%**	**46%**	**53%**
10%	**9%**	**13%**	**16%**	**19%**	**22%**	**25%**
20%	**4%**	**6%**	**7%**	**8%**	**9%**	**11%**
30%	**3%**	**4%**	**5%**	**6%**	**7%**	**8%**

Table adapted after V.A. Munroe

NOTE: the assumption of 35% energy savings in Table 1 is not far-fetched. It should be remembered that worldwide experience has shown that mere improvement in ordinary housekeeping practices (i.e., minding the energy connotation of everyday work, such as switching off unneeded equipment, etc.) typically produces 10-15% savings!

Encourage the team members to keep up with their assigned work and to stick to the implementation schedule. Meet with the energy management team (EMT) in regular, brief meetings, to review progress, plan new projects, evaluate established goals and set new goals as required.

Establish ongoing monitoring

It is important to track the energy streams entering the facility and their usage. It will generate data to provide answers for the following questions:

- Is progress being made?
- Are the energy data accurate?
- Can we make prompt corrections of process conditions that have caused sudden excessive consumption?
- What are the trends in energy usage? (Use that information in the budgeting process.)
- What is the cost savings achieved from data gathered by the energy monitoring system, and what is the return on investment?
- Are the implemented energy saving measures living up to the projections? (Problems with the project's performance can be identified and techniques for estimating costs and benefits of energy efficiency improvements for future projects can be improved.)
- Is the equipment performing as per the supplier guarantees?
- Can we set future energy use reduction targets and monitor progress toward new goals?

Establish ongoing monitoring (Continued)

- Are there areas in the facility, which need a detailed energy audit?

The best way to monitor energy consumption is done with metering equipment installed at strategic points to measure the flow of energy sources, such as electricity, and compressed air to each major user.

Express the energy performance meaningfully

Express measurements in SI units, such as MJ or GJ. They are preferred, as they enable global comparisons. For example, state the energy consumption or savings in this way:

> ***Consider expressing energy usage in the global warming context, where***
> **1 MJ = 0.2 kg CO_2 equivalent**

- Per hL of saleable beer
- Per investment dollar
- Per dollar of sales
- As power saved
  (or gas, steam, compressed air); state also its equivalent in dollars
- As annual operating cost savings
- As capital cost avoidance

> ***Use the measurements that make sense in your brewery's specific conditions.***

Monitoring energy performance helps managers identify wasteful areas of their department and let them take responsibility for energy use. When monitoring shows that energy consumption is declining as improvements are being made, attention can be turned to the next area of concern.

Lock in the gains – set new targets

> **Remember that energy management is an issue of technology as well as people.**

Energy management needs constant attention, otherwise the gains could fade away and the effort could disintegrate. To make the new energy saving measures stick, pay a sustained attention to the implemented project until such time when the measure has become a well-entrenched routine.

If practices and procedures have been changed because of the project, take the time and effort to document it in a procedure or work instruction. That will ensure the future consistency of the practice, as well as serve as a training and audit tool.

6.4 Monitoring & Targeting (M&T)

Since its inception, the Monitoring & Targeting (M&T) energy and utilities management system has become a mainstream methodology. Several firms are successfully selling the underlying hardware and software, applicable in a wide range of industries. In brewing, it was the U.K. Brewers' Society (now Brewers and Licensed Retailers Association) who first proposed its use.

It is a disciplined and structured approach, which ensures energy resources are provided and used as efficiently as possible. The approach is equally applicable to other utilities, such as water, CO_2, nitrogen, effluent, etc.

In Canada, the Molson brewery in Toronto-Etobicoke was the first to implement it, with rather spectacular results. These were published. (Energy Services, Case Study No. 1, Ontario Hydro, December, 1994). According to the report, an initial $200,000 investment realized savings of about $1.5 million on water charges alone in the first year of implementation. Since then other breweries in Canada have implemented the M&T technology.

M&T does not imply any changes in the specifications of processes. It does not seek to stress the importance of energy management to any greater or lesser extent than is warranted by its proportion of controllable costs. The fundamental principle of M&T is that energy and other utilities are direct costs that should be monitored and controlled in the same way as other direct production-related costs such as labour and malt. As such, actual energy use should be included in the management accounts in the same way as labour or malt is included.

Accountability for controlling energy consumption should rest with the people who use it, namely the brewery's departmental managers. The plant controller should also be involved since this is the person who will want to know how these controllable costs are managed.

The direct benefits of M&T have been shown in the brewing and other industries to range between 4% and 18% of the fuel and electricity bills. Other, intrinsic benefits lie in beneficial change in the culture in the brewery, increased employee awareness, a sense of ownership, an improved environmental posture of the brewery, and the application of the newly acquired energy–saving habits in other aspects of production.

The costs of implementing an M&T system will depend on the extent of installed metering, the coverage desired and the methods used for recording and analyzing energy use. Scope can be adjusted in line with the savings expected.

The road to improved energy efficiency begins with a board-level policy to treat energy and utilities costs as direct costs. The policy is implemented through a proper management structure. Implementation is assisted by monitoring consumption against standards and set targets that have been agreed upon by the managers. All employees must also be on board in order to achieve the targets.

The M&T process begins with dividing the brewery into energy-accountable centres (EACs), some of which convert energy and others that use it. An EAC should correspond to an existing management accounting centre such as the brewhouse. For obvious reasons, EACs should not straddle different managers' jurisdictions. Within each EAC, energy consumption, e.g., use of steam, electricity, etc., is monitored. For additional control, energy might be monitored in specific areas within the EAC. For each item monitored such as boiler efficiency, a suitable index is needed against which to assess performance. For each index, performance standard needs to be derived from historical data that take into account those factors (e.g., production) that can significantly affect efficiency. Again, the managers involved must agree upon the derived standards.

Targets are derived, just as standards are. They represent improvements in energy use efficiency. To insure that the process will work, the managers having their consumption targeted must agree that the targets are realistic. Examples of the parameters (specific consumption figures) that could be measured are shown below:

Table 6.4.1: Deployment of M&T (example)

Brewery Process Areas	**Measurement**
Brewhouse	Consumption/hL cold wort
Fermenting	Consumption/hL cold wort
Cellars/beer processing	Consumption/ hL bright beer
Packaging	Consumption/ hL shippable beer
Energy centre:	**Measurement:**
Refrigeration	Consumption/ GJ cooling
Steam production	Consumption/ GJ heat
Air compressors	Consumption/ Nm3 air
CO2 collection	Consumption/ kg treated CO2
Other functions	Consumption/ week

Measuring requires installation of meters at key points in the system, especially at equipment with large energy or utility consumption (such as the brew kettle, bottle washer and can filler).

To generate data, the following matrix of metering equipment should be installed as a minimum:

Table 6.4.2: Installation of energy and utilities meters (example):

Meters for / in	BH	F	CP	PKG	EC	REF	STE	CO_2	CA	OTH
Cold water	X	X	X	X	X	X	X	X	X	X
Hot water	X	X	X	X	X					X
Steam	X	X	X	X	X		X	X		X
kWh	X	X	X	X	X	X	X	X	X	X
Compressed air				X	X					
CO_2			X	X	X			X		
Refrigeration					X					

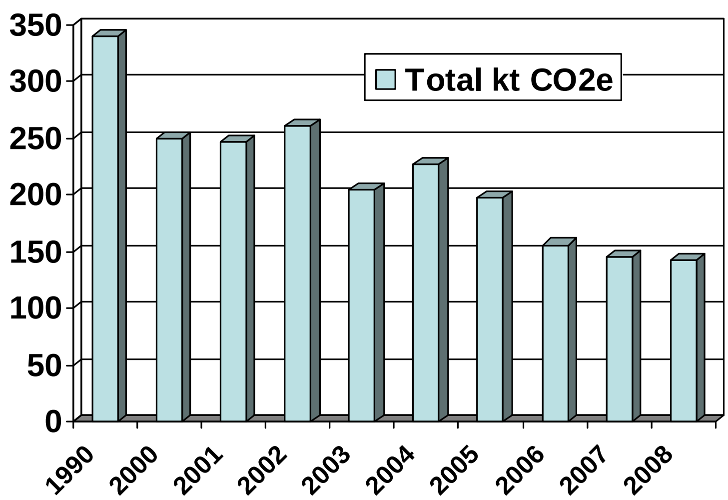
Note: BH – Brewhouse, F – Fermenting, CP – Cellars/beer processing, PKG – Packaging, EC – Energy centre, REF – Refrigeration, STE – Boilerhouse, CO_2 – Carbon dioxide recovery plant, CA – Compressed air, OTH – Other areas

Experience has shown that the cost of installing the meters and the associated monitoring equipment will soon be offset by the gains ensuing from the M&T program. It takes about 18 months from the initial decision to investigate the M&T potential to full implementation of the system.

The M&T concept is sound, and many industrial sectors have benefited substantially from it.

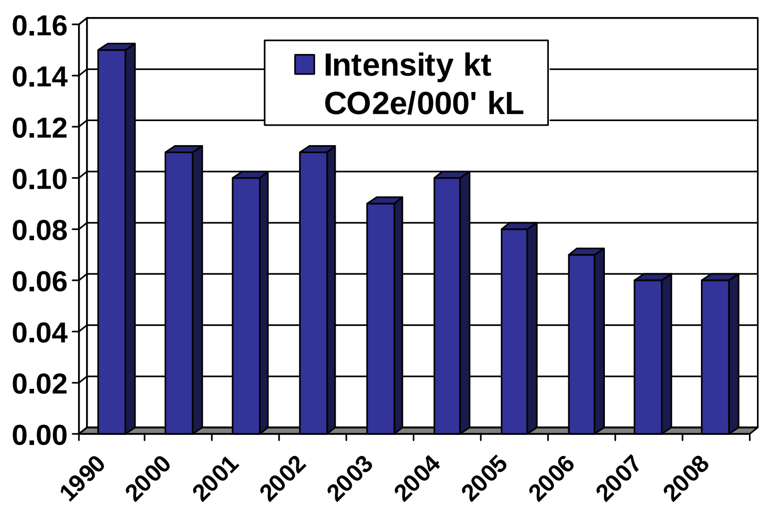
7.0 BREWERY EMISSIONS AND GLOBAL WARMING

The Canadian brewing industry generates annually an extremely small fraction of Canada's total carbon dioxide emissions – this gas being a chief contributor to greenhouse gases (GHG) implicated in global warming. In 2008, the sector produced some 140,000 tonnes of the CO_2 gas equivalent [2] a substantial improvement from the 1990 baseline, when the total emissions stood at 340,000 t CO_2e. This is shown on the following graph:



The breweries can help reach Canada's reduction objective, while helping themselves, by improving the efficiency of energy use in their operations.

When it is related to the volume of beer produced in the period (from 22.56 million hL to 23.66 million hL in 2008), we see that the so-called **CO_2e intensity** has dropped similarly:



[2] Data Sources: Energy Use - Statistics Canada, Industrial Consumption of Energy Survey, Ottawa. December 2008; Brewery production - Brewers Association of Canada. Ottawa. October 2008. brewery

The drop of so-called **CO_2e index** corresponds to that, too: from the base index 1.00 in 1990 down to 0.40 in 2008 – a 60% decrease.

This is supported by industry information, e.g., by 2009 Corporate Environmental report coming from Molson Coors, which indicated 13% drop of CO_2e emissions between 2006 and 2007 in Canadian brewing operations.

As an industry sector participant in the Canadian Industry Program for Energy Conservation – CIPEC – the Brewers Association of Canada (BAC) is working to help Canada meet its international climate change commitments. One of the ways is its initiative in having this *"Guide"* updated.

> BAC created an interesting visualization of the advances the Canadian brewing industry has made in GHG emissions reduction since 1990 till 2007. The energy conservation efforts resulted in the equivalent of 25 2265 cars being taken off the road, about 1486 cars per year!

Can we be happy with the results? To a degree, yes. People the world over are feeling increasingly concerned about the health of the environment they live in and the global warming effects of greenhouse gases. More needs to be done in our breweries on further reducing the consumption of energy in all its forms.

To start, an energy management program offers a unique opportunity to marry the goodwill most people feel towards doing something positive for the environment with achieving a business objective of reducing energy consumption. These two objectives go hand in hand.

Improved energy efficiency reduces greenhouse gas emissions in two ways:

- Energy efficiency measures for on-site combustion systems (e.g., boilers, heaters) reduce emissions in direct proportion to the amount of fuel not consumed.
- Reductions in consumption of electricity lead to reductions in demand for electricity and, consequently, reductions in emissions from thermal electric power generating stations.

For an example of how to calculate the amount of reductions in major greenhouse gases emissions resulting from your energy efficiency projects, look up the Appendix 9.3 – point 9.3.1: Calculations of emission reductions.

Additional treatment of the topic is in section 8.3.2 – Environmental impact of boiler combustion.

Since we look at the environment in the global sense, it is irrelevant that the emission reductions occur at the electrical generating station rather than at the site of the efficiency improvements.

Breweries must also pay attention to the composition of their air emissions. For example, the March, 2001 air quality standards in Ontario set tougher limits to meet. Projects designed to meet emission standards can be capital-intensive. A project, spawned by a regulatory requirement, can be easier to justify by combining it with an energy management project that reduces energy usage.

7.1 Calculating carbon footprint

An off-shoot of the concerns with global warming has been an effort to manage carbon dioxide emissions globally by emissions trading. Wikipedia defines it as:

> "**Emissions trading** (also known as **cap and trade**) is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants.
>
> A central authority (usually a governmental body) sets a limit or *cap* on the amount of a pollutant that can be emitted. The limit or cap is allocated or sold to firms in the form of emissions permits which represent the right to emit or discharge a specific volume of the specified pollutant. Firms are required to hold a number of permits (or *credits*) equivalent to their emissions. The total amount of permits cannot exceed the cap, limiting total emissions to that level. Firms that need to increase their emission permits must buy permits from those who require fewer permits. … The transfer of permits is referred to as a trade. In effect, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emissions. Thus, in theory, those who can reduce emissions most cheaply will do so, achieving the pollution reduction at the lowest cost to society."

It is obvious, then, that for economic reasons as well as environmental, it is desirable to know the amount of emissions one produces, to know the company emissions' impact on the environment – so-called **carbon footprint**.

Determining a carbon footprint is a new business in which many companies are now involved. The Internet is full of references to various sites, providing this service, such as *www.carbonfootprint.com/calculator.aspx* or *www.nature.org/initiatives/climatechange/calculator/*

The math is rather simple: it is necessary to know the annualized consumption of energy in all its forms in the brewery (electricity, natural gas, LPG, fuel oil by type, propane, diesel fuel and gasoline for emergency power generators, lift trucks, trucks and cars the brewery operates), even the average fuel consumption in cars and trucks, the total mileage driven by the brewery staff while distributing product and on business trips by car or airplane. Using the emissions converter (some of the equivalents are shown in the tables in the Appendix 9.3) one calculates the total emissions as metric tonnes (t) of carbon dioxide equivalents, **CO_2e**, and summarizes them.

Generally, the following relationships in calculating the Global Warming Potential (GWP) of the emissions have been established:

Table 7.1.1 Global Warming Potential (GWP) of the emissions

Baseline Emissions		GHG	CDM Project Emissions		Net Reduction		GWP[a]		CO_2e[b]	
0	-	CO_2	0	=		x		=		
0	-	CH_4	0	=		x	2	=		
0	-	N_2O	0	=		x	31	=		
0	-	HFC-23	0	=		x	1170	=		
0	-	HFC-125	0	=		x	280	=		
0	-	HFC-134a	0	=		x	130	=		
0	-	HFC-152a	0	=		x	14	=		
0	-	CF_4	0	=		x	650	=		
0	-	C_2F_6	0	=		x	920	=		
0	-	SF_6	0	=		x	2390	=		
0		**Totals**	0							
						Grand Total				

[a] Global Warming Potential as related to CO2.
[b] Carbon dioxide equivalent.

Source: BAC/CO2 Equivalent Calculator (Beta) – adopted
Note: All units should be converted to metric tonnes before keyed into the calculator. You only need to provide values for the Baseline Emissions and CDM Project Emissions columns (green colored cells). Indicate 0 (zero) for empty fields. To avoid errors, make sure to hit all the Calculate buttons before hitting Total.

The relationship, as well as the simple calculation formula involved (above), can be used with advantage when an energy use reduction project is contemplated in the brewery (e.g., in a burner retrofit job for the boilers). This type of calculation backed up by flue gas analyses, enabled, for example, Great Western Brewing Company, to demonstrate that the comprehensive review of boilers, particularly the retrofitting of the burners, brought the NO_x emissions down to California standards.

Simple and rather empirical relationships, which have relevancy to energy efficiency projects in a brewery, include the following:

Energy equivalency in CO_2:

1000 kWh = 720 kg CO_2e
= 3600 MJ
= 18.4 tree seedlings sequestering that amount of CO_2 in 10 years
1 MJ = 0.2 kg CO_2 equivalent
200 MJ/hl beer = 40 kg CO_2 equivalent

(Sources: *www.carbonwatch.com/**calculator**%20-%20GHG.htm*
*www.epa.gov/RDEE/energy-resources/**calculator**.html*

The value of these conversions will come out when the Energy Management Team popularizes its work and its beneficial environmental impact.

7.2 Carbon footprint calculations elsewhere:

Are you interested in some actual figures? In an UK report (IBD MBAA paper by Gordon Jackson et al., 2009) the topic was reported (abbreviated as shown):

"Increased market pressures on publication of carbon footprint were showed in at least one UK supermarket chain requesting their suppliers to provide that information on over 150 products in its stores.

There is little data available on carbon footprint for beer brands. Additionally, it is difficult to compare existing data because of lack of carbon footprinting standard. The UK PAS2050 standard, now in draft stage, may become the international standard for carbon footprinting.

A comparison of data published in corporate reports for international brewers shows the carbon footprint – as kg **CO_2e** per hL – for Asahi 10.5, Fosters 14; Heineken 10.5; InBev 13; Grupo Modelo <16; SAB-Miller >12.

(However, the New Belgium Brewing Company's analysis showed the total carbon footprint (using their main, Fat Tire brand) – as kg CO_2e per hL – of 27.9 for malt production and transport; 5.8 for brewing process; 40 for packaging materials (of which 32.3 was accounted for by glass production); 12.9 for distribution; 12.3 for storage in the outlet and 2.4 for waste disposal.)

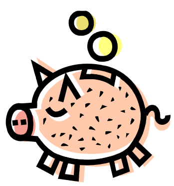
8.0 TECHNICAL AND PROCESS CONSIDERATIONS

Energy management must be approached with an open mind to critically evaluate previously accepted practices, some of which may prove to be inefficient. A fresh look, or an added awareness, which this chapter aims to supply, combined with a little imagination and/or expert assistance, can pay large dividends in energy and cost reduction.

This chapter describes what can be done with energy and water conservation in the brewery processes, listed below.

The energy efficiency improvement opportunities (EMOs) and tips are roughly categorized – as pointed out in the “introduction” chapter – into three categories, with attached symbols – as follows below.

The dollar division is approximate, as it is normally the function of the size, type ad financial policy of the organization. Also the payback period is estimation only, based on the type and complexity of a project.



Housekeeping, no or low cost (payback period is six months or less):

Medium costs (retrofit of equipment or buildings required; payback period is 3 years or less):

Capital Cost (process change, new plant or equipment required; payback 3 years or more): generally speaking, these energy efficiency

Tips of Interest particularly (but not exclusively to small breweries are highlighted in blue font.

8.1 Fuels

This section is intertwined with the description of the boiler systems in 8.3. They should be read together.

Mainly for reasons of due diligence and emergency preparedness, most Canadian breweries opt to secure non-interruptible operations by running their boilers on dual fuel, usually natural gas and oil. The exceptions may be in regions that are not served by natural gas pipelines. In addition, the ability to burn different fuels provides leverage to negotiate better prices in supply contracts. A third advantage is in the flexibility of fuel choice over the long-term, should a change in availability or relative price occur.

The choice of fuel requires careful consideration. Factors, such as capital cost of the plant, the price of fuel, its current and anticipated future supply, and operating and maintenance costs, all have to be evaluated.

As most of the boiler plants in Canadian breweries are ageing, these considerations will come into play when deciding on a retrofit or replacement of the plant. Also for brewing companies, which are considering a start-up of new operations, the following table may be of interest:

Table 8.1.1 Comparison of fuel types

Fuel Type	Advantages	Disadvantages
Natural gas	➢ the most convenient to use ➢ readily available ➢ no storage required ➢ mixes with air readily ➢ burns cleanly ➢ high calorific value ➢ does not produce smoke or soot because it has no sulfur content ➢ heat recuperation possible from flue gases beyond the point at which condensation starts ➢ lighter than air ➢ if leaking, will disperse easily	➢ maintenance of safety equipment required

Table 8.1.1 Comparison of fuel types (Continued)

Fuel Type	Advantages	Disadvantages
Liquefied Petroleum Gas (LPG) (usually propane; sometimes butane)	➢ All the general comments about natural gas apply equally to LPG.	➢ requires storage facilities (capital or leasing costs, operational and maintenance costs, inspections and testing of storage pressure vessels and delivery systems) ➢ special precautions needed in relation to leakages ➢ heavier than air ➢ may seep into underground tunnels, ducts ➢ requires forced dispersion with a fan (storage siting consideration) ➢ LPG butane, although slightly cheaper, liquefies at 0 ^{o}C ➢ needs power source for evaporation at low temperatures
Heavy oil ("Bunker oil"); No. 6	➢ cheaper than lighter grades, sometimes cheaper than gas	➢ requires storage systems ➢ capital and maintenance intensive ➢ potential for leakage and soil/water contamination ➢ regular inspections required ➢ due to high combustion temperatures, it produces oxides of nitrogen (NOX) ➢ high sulfur content may preclude utilization of flue gas economizers due to ➢ corrosion problems arising from condensation and formation of acids from sulfur oxides (SOX) ➢ very viscous, needs insulated and heated storage tanks and pump/pipe delivery systems ➢ the pumping circulation loop must be kept at a high temperature ➢ thorough atomization in the burner required ➢ may produce smoke or soot ➢ boiler cleaning and burner maintenance costs
Light oil (e.g. No. 2 oil)	➢ partially desulfurized to 0.1 to 0.3% sulfur content; ➢ remains fluid to -11 ^{o}C	➢ gels in extreme cold ➢ waxes may precipitate in cold weather ➢ may clog filters ➢ requires heat tracing ➢ other properties are similar to heavy oil

Other fuel considerations:

The use of coal, coke and wood, is not generally practiced in the brewing industry in Canada. A brewery in the United States reported using solid combustible waste to supplement its energy needs.

Biogas from the operation of anaerobic wastewater treatment plants – WWTP- (predominantly methane with heavy contamination with CO_2) can be used with advantage. Because its volume generated is dependent on the WWTP operation, it has a supplementary role to the use of other fuels. Its relatively low volume (if used on the stand-alone basis) is thus usable for smaller dedicated tasks, such as for preheating the return condensate or air intake, or for water heating. Because it is wet, corrosion of the supply system may be a problem. At least one Canadian brewery is practicing it, though.

In the three Canadian Western provinces the marketplace for the natural gas industry has long been competitive. Ontario and Québec also have got used to the deregulated market conditions. The natural gas prices have risen sharply starting since 2000. Energy efficiency and demand side management (DSM) will be increasingly important tools for breweries to manage costs. Large users of natural gas are purchasing gas on the spot market and are using software to manage the task for the maximum financial benefit. While escalating gas costs are a major factor in energy budgets, at least one larger company have managed to offset them by installing combined heat & power (CHP) co-generators for generating their own electricity and selling a potential surplus to the distribution net. Other may follow suit when business conditions allow it.

The priority in reducing natural gas or fuel oil consumption is to concentrate on making the combustion process as efficient as possible. These points should be examined:

Gas/oil delivery system

> Is it tight, without obstructions and leaks? Gas lines, many of which may be decades old and buried underground, may have corroded and have leaks. How to find out whether they are leaking: during a no-production period, record the gas meter reading and check it again after a 12-24 hour period. Providing that not even the gas water heater was on, there should be zero difference. (Account for legitimate gas consumption for space heating, etc., by estimating the consumption based on the plate information.) Otherwise, leaks may be indicated, and work should start on uncovering their source and fixing them promptly (safety may be involved!). Similarly, check the tightness of the oils system, albeit with a lower accuracy and requiring a longer time interval. If suspect, surrounding soil analysis may provide an answer.
>
> In oil supply systems, ensure that filters are regularly checked, and pumps maintained.

Combustion

Very frequently, adequate controls are lacking for oil and gas furnaces. Poor control of air/gas ratio results in wasted energy, frequently excessive temperatures and wasted money. More on the topic is in section 8.3.

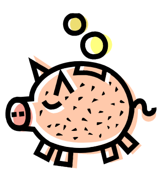
Flue gas analysis will show the true composition. For natural gas, under equilibrium conditions, the flue gas composition should show close to 12% CO_2, about 20-22% of water vapour and the rest nitrogen. Lower percentages of CO_2, and the presence of carbon monoxide (CO) and hydrogen, indicate poor combustion (reducing fire) and chemical energy losses in the two escaping gases; a portion of the gas has been wasted. On the other hand, in excess air supply conditions, all the gas will be burnt, but the analysis will reveal the presence of oxygen. Again, energy was wasted, this time on heating the extra air passing through the boiler furnace.

Air-tightness of the boiler furnace chamber

Air ingress into the boiler furnace causes significant losses of energy. All that extra air needs to be heated to maintain the proper furnace chamber temperature. Attention to air elimination from the steam, boiler and pipes insulation, and steam traps maintenance are also important points in making the system efficient. Some of the EMOs, specific to steam boilers, are listed below.

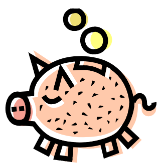
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Inspect gas/oil lines for corrosion and other sources of leaks to ensure no losses are occurring
- If underground oil tank or pipes are suspect of leaking, consider contracting for analysis of surrounding soil: it will cost, but it may save much more by avoiding much larger soil decontamination cost!
- Inspect the aboveground fuel oil tank insulation and supply pipes insulation; repair it without delays
- The gas company can be approached with a request for a loan of extra gas meters for sub-metering major gas-burning equipment
- Avoid heating the entire oil storage tank to the required pumping (circulating) temperature, it is wasteful. Control the temperature of oil in the storage tank to maintain viscosity required for pumping oil; verify it
- Avoid having too much oil in the circulating loop; a well-designed pumping system circulates only 10% of oil over the maximum demand of the burners

Housekeeping, no or low cost



(Continued)

- Ensure that electric heat tracing works and is used only when necessary
- If steam is used for tracing, evaluate the cost vis-à-vis electric tracing
- Subject gas suppliers to competitive bids
- If the boiler is dual fuel-fired, review your gas supply contract and consider an interruptible supply option that carries a lower gas price

Medium cost

- Consider installing gas flow meters to manage the consumption of the major gas using equipment – such as boilers and water heaters
- Monitor and control the boiler furnace inside pressure
- Consider using the local gas company as a contractor for maintenance services to your gas burners
- Your local oil supply company can help with efficiency testing and off-gas analyses

8.2 Electricity

Managing electricity:

> *Power consumption costs in air compressors and in packaging are by far the most important end-use points to control!*

The effort to save electricity at a brewery could start with examining the components of its electricity bill. Often these are not fully understood and consequently advantages of available savings are not utilized. A brewery can leverage this knowledge profitably in managing electricity use on site, and in negotiating with energy companies in the deregulated electricity market in Canada.

The electricity bill may have four components:

1. **Consumption charge** – the kWh consumed in a given period multiplied by the set rate, in ¢/kWh. A second consumption charge may apply in time-of-use and seasonal rates situations. These pricing schemes offer lower rates to customers who can shift high-demand operations away from the periods when the utility receives its peak demand for energy. The utility benefits from a more consistent daily load pattern, and the customer pays less.

The means to save:

- ➢ Reduce the total electricity consumption (in kWh) in the facility
- ➢ Shift energy consumption to a time when energy costs are lower

2. **Demand charge** – the maximum power level used by the brewery, in kW or kVA, also called peak demand. The demand varies throughout the day in dependence on what electric equipment is running concurrently. The electric company measures the demand in 15-minute intervals, every quarter hour. The maximum demand recorded in the month sets the demand rate (up to $20 or more per kW) to be applied to the electricity bill for the entire (!) month. The electricity utility thus finances its investment in supplying the required power to the brewery. If the brewery has its own transformer, it may negotiate for a discount.

In breweries, the potential for cost savings from demand control and load shifting is excellent!

Some billing practices obscure the penalties involved. For example, if the demand charge combines the monthly demand with a percentage of maximum monthly demand in the past 12 months, then a brewery is penalized when no production takes place (on account of holidays or poor business).

By simply managing the time when electricity is being used, considerable savings are possible.

The means to save:

- ➢ Reduce peak demand by:
  - Load-shedding – i.e., turning off non-essential electrical equipment
  - Load-shifting – i.e., re-scheduling operations so that some activities take place during off-peak periods
  - Process improvements, which reduce electrical power requirements
  - Negotiating, if the utility allows it, for 60-minute demand- setting period, instead of the 15-minute one

One of the main strategies to save power is to reduce the non-productive idle time in the production – this helps even out the load.

- ➢ Control demand by demand controllers – the devices, which reduce potential peaks and make a brewery‘s operations to add load to the low spots. If you already have a demand controller, examine its function relative to a frequency of load

To achieve good power demand, find a substantial load, which can be taken off line instantly without creating intolerable production disruption or delay.

factor peaks. Demand can be also controlled by staggering of operations and using new-generation power packs, which can split the power between the user centres to control the demand effectively.

Fig. 8.2.1 Load shedding

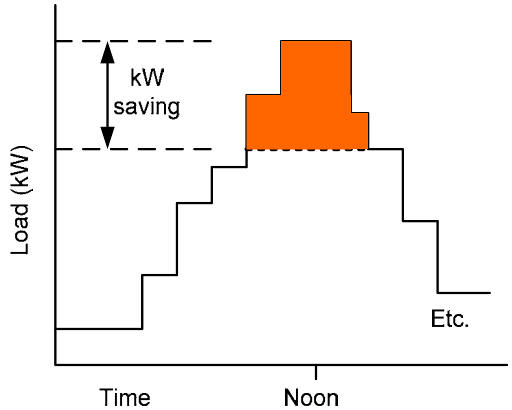
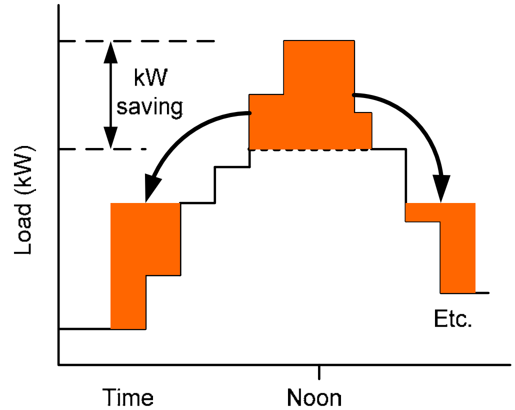


Fig. 8.2.2 Load shifting



3. **Power factor charge** – a penalty that the electric company charges to customers with poor utilization of the power supplied**;** it is a measure of efficiency. It is expressed as a ratio of the power passing through a circuit (apparently supplied, in kVA), to actual power used (work performed, in kW). Utilities penalize customers with power factor less than a set level, usually 90%. The deregulation affected this and other penalties.

> *Power factor penalty is often obscured when the demand is billed in kVA, rather than the maximum kW level.*

Sometimes, kVA is used in the capacity charge. It is a charge intended as payment for the costs of supplying the service to the site, and represents the maximum demand from the supply system.

<u>The means to save:</u>

Power factor may be improved by:

- ➢ Controlling items that generate inductive loads, such as transformers, lighting ballasts, electric induction motors (especially under-loaded ones), etc., which lower the power factor.
- ➢ Installing capacitors in the electric system. (The thing to watch for is harmonics from other equipment that may trip or destroy the protection.)

4. **Inducements** – e.g., offering different rates for blocks of consumption based on demand (e.g., 9 ¢/kWh for the first 100,000 kWh x demand, 6 ¢/kWh for the next block, etc.). This may penalize single-shift operations and those with a poor load factor. (Load factor is the monthly consumption divided by the product of maximum demand and the billing period hours.)

At other times, utilities may offer better rates for off-peak hours in the effort to make a brewery reschedule its operations (e.g., refrigeration).

The means to save:

- Examine your electricity bill and try to re-negotiate
- Examine the economics of a different production schedule

Most industrial and commercial facilities are billed for electricity according to a general-service rate schedule in which the customer pays for the peak power demand (kW/kVA) and energy consumption (kWh). Most general-service rate structures also impose financial penalties on plants with a low power factor.

Real-time pricing allows the customer to schedule its high-consumption activities to low-cost times of day and to realize substantial savings.

Some utilities now offer their major customers real-time pricing, a scheme, in which each day, the utility gives the customer the rates proposed for each hour of the following day.

Softwares are available for estimating energy costs in a variety of situations to help you arrive at the best mode of use, depending on operational restraints imposed by factors such as equipment requirements. To find out more about available software and analysis tools, consult your electrical utility. (Also, see EMOs below.)

*It is estimated that potential electricity cost savings from demand control or scheduling are **4 x** greater than those from energy conservation are.*

Consider using one of the predictive, "smart" Demand Side Management (DSM) programs, which are available on the market. DSM refers to installing efficiency devices to lower or manage the peak electric load or demand. (Note: DSM programs are available also, e.g., for natural gas usage.) A network of on-line electrical metering enables real-time data to be collected from the meters, and the computerized energy management system to predict and control the electrical demand. When the demand approaches pre-set targets, non-essential operations are cut off and held back so as to shave the peak demand.

Breweries in Canada buy their electric power from public utilities, with the exception of a single brewery, which employs in-house generation.

In conserving electricity, focus on where the potential savings are!

Remember also, that the effort must be broad-based and have the support of the operators. An awareness campaign should be at the start. Ask yourself: "Are the employees aware of the electricity, fuel and utilities costs, and of the level of those expenditures in the plant? Do we have an effective communication system in place to share the results of the conservation efforts with everybody?"

Benchmarking tools, e.g., EnergySaver®, are available from www.bri-advantage.com.

Case study: Beginning the practice of monitoring electric demand

By charging their customers a cost penalty for peak kilowatt demand during each month, electric power companies are encouraging them to reduce power spikes in their operations. It is costly for power companies to maintain sufficient reserves to cope with spiked demand, as they are compelled under the law. Power companies customarily measure the demand in a plant over consecutive 15- or 30-minute intervals throughout the month. The peak kilowatt-hour demand then is selected and determines the kilowatt demand rate that applies to the chosen period (usually daytime hours).

The peaks in demand are caused by a number of factors, as discussed elsewhere in this *"Guide"*.

The most important factors are the starting of large motors and the starting of many motors of any size in a single 15-minute period. The reason is that at start up, electric motors can draw between 5 and 7 times their full load currents. Those current spikes will last until the motor has reached nearly full operating speed. For fully loaded motors the spike can last anywhere between 30 seconds and 2 minutes. **Hence the importance of a selective, gradual starting up of the packaging line in the morning and timing use of other large power-using equipment to off-peak times.** The management side of start-up sequencing can be aided by hardware solutions such as sequencers on air conditioning systems or soft-start devices on large motors, which are particularly effective in reducing the peak demand by nearly 100%. At any rate, installation of a demand meter with a printout (or telemetry provision) is a necessary tool in the effort to control peak demand.

The demand spike due to starting a fully loaded motor is approximated by the following equation:

$$DS = \{(N \times f \times \Delta T) + (N \times Tr)\} : T \text{ ; where:}$$

DS = demand spike, kW

N = motor size, kW

f = increase in current during start up (e.g., 6 times)

ΔT = time that the increased current is drawn (e.g., 1.5 minutes)

T = time over which the power company measures demand, minutes

Tr = time remaining in the measurement period ($T - \Delta T$)

The reduction in the demand spike from the implementation of the soft start devices will result in savings equal to the difference (DS – N).

In dollar terms, the savings can be calculated according to the formula:

$$S = R \times (DC/kW\text{-}month) \times AD \text{ ; where:}$$

S = monthly savings, $/y

R = average demand reduction, %

DC = peak demand charge, $

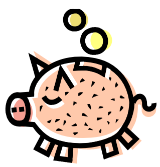
AD = average demand

In a plant with an average demand of 959 kW and an average peak demand kW charge of $13.60/kW, and assuming that the peak demand can be reduced by at least 15% through careful control, the savings per annum amount to $23,600.

If the demand meter with a printout is $3,750, then the simple payback is only 0.2 years.

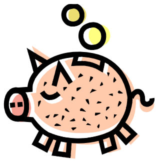
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Involve all employees – the electricity conservation effort must be broad-based and have the support of the operators. An awareness campaign should occur at the start
- Review the scheduling of brewery operations in view of the factors in the cost of electricity they consume
- Establish a baseline of power consumption during plant shutdowns, on Labour Day, Thanksgiving Day, etc., for energy use tracking
- Track and trend power consumption based on production and non-production days to spot the energy wasters. Then, develop procedures and shutdown checklists to ensure that equipment shutdowns are taking place
- Identify large consumers of electricity (e.g., refrigeration compressors, air compressors) and list them together with the related percentage of total electricity usage
- Consider:
    - staggering the starts of the equipment with heavy power consumption or reschedule production to lower demand (e.g., do not start the equipment in the packaging area all at once at the beginning of the shift; start it up as required and shut it off as soon as it is finished
    - charging batteries, filling up water reservoirs, and operating other "can wait" power users during off-peak periods

Housekeeping, no or low cost



(Continued)

- shutting down (even briefly) other non-essential loads at peak demand periods, such as additional aerators in a wastewater treatment plant (WWTP), heating, ventilating and air conditioning (HVAC) equipment, yeast room and fermenting and storage cellar refrigeration that works in high thermal inertia conditions (i.e., where substantial time will elapse before a change of temperature of a large mass occurs, such as in case of large tanks full of chilled beer), etc.

- Verify that motors are correctly sized for the job
- Install automatic controls for shutting down equipment when not needed
- Switch off all unneeded equipment (e.g., during lunch breaks, shift change, weekends …)
- Turn off unnecessary lights
- Consider installing photocell-driven switches and motion switches where feasible (packaging halls, corridors, cellars, warehouses, outside lighting, etc.)
- Review motor burnout history and whether circuitries in the brewery need to be upgraded
- Maintain and calibrate automatic controls on all equipment
- Control harmonic distortion passively and upstream: specify it in new equipment buying standards
- Use the electric utility as a resource: they can make suggestions as to demand reduction alternatives, points for metering, the way to measure consumption, possibly to loan an load analyzer
- Request a load profile from your electric utility company
- Ask your electric utility for advice on how to reduce consumption, reduce peak demand and improve power factor
- Request from federal, provincial or municipal governments and the utility, information on programs and financial incentives that may be available for equipment modifications and replacement
- To take the best advantage of tariffs, consider fitting a load analyzer to the brewery power supply to obtain a pattern of loading and major uses. Compare results with tariff rates and annual costs. Examine different possible scenarios for optimum results
- Consider conducting thermographic inspections of the brewery for heat losses, but also for detection of electrical hot spots, e.g., in a couplings and contacts, which indicate mechanical sources of losses

Medium cost

- Replace driven equipment with more energy efficient equipment
- Replace (especially large) standard electric motors with high-efficiency types when replacement is necessary
- If feasible, replace, as a matter of purchasing policy, old worn-out electric motors with new high-efficiency motors
- Install variable speed drives, soft-start options and improved controls on electric motors
- In pumping systems, minimize wasteful and costly by-pass provisions
- Increase power factor to 0.95 or better. The power factor is the cosine of the angle by which the current and voltage differ.
- Reduce the penalty from the electrical utility for inefficient operation by:
  - replacing lightly loaded induction motors with ones correctly sized for the job
  - Installing capacitors. Capacitors create a “leading” power factor to counter the “lagging” power factor of the equipment and can be installed on the individual equipment or as a multiple unit to control a part or the whole of the distribution system.
  - Through periodic inspections, verify that the capacitors are working as designed. The payback period is usually in the order of 18 months
- Consider installing power load-shedding software in the EMC. (The software serves as an electricity and process management tool. It monitors power usage instantaneously and adjusts to a set target for maximum level of power it can use. It governs the consumption through a PLC. It can express real and predicted usage of power in kWh and also in terms of costs; e.g., PowerPlusReporter® software; environmental and energy management programs from E2MS company)

Capital cost

- Consider installing and using an internal combustion engine-driven, stand-by generator for a few hours daily to shave off the peak demand, particularly in winter. The tariff savings are significant
- Install a computerized automatic system for monitoring and controlling electrical and thermal energy consumption and utilities (particularly in large breweries); use it for application of the monitoring and targeting (M&T) technology
- When installing an energy management system, choose one with both analytical and reporting capability
- Consider replacing power capacitors with microprocessor-based LRC tuning circuits, sized for each specific equipment and power load, to control the power factor for improved savings

8.2.1 Alternate sources of (electrical) energy:

The following is just a "memory jogger" bringing to mind other, unconventional sources of energy that are gaining recognition worldwide. It is just a listing, because a detailed elaboration on those modes would be beyond the scope of this *"Guide".* Specific technologies for tapping into those – such as wind, solar, geothermal, fuel cells, biogas, biomass, although young in most cases – have been already proven as viable. It is an emerging trend that follows on governmental directives worldwide, as a part of state policy, to wean industries in part from conventional energy sources to renewables. Targets were already set for future years, to ensure lessening a state's dependence on imported fuels and electricity. That has happened in Canada just as in the United States and in Europe.

Considering them is not necessarily a domain of only "big" brewery concerns. Already, a small Canadian brewer is weighing their options for installing **solar electricity** panels and for **geothermal** pumps.

Alternate energy sources are already used by a U.S. small brewery, Sierra Nevada Brewing Company. According to a private communication, they have employed a visionary policy regarding energy. It is instructive even for us in Canada, where the conditions and climate may be different, to learn from them as follows (quote):

"One can generate all the green power in the world, but if that energy is not used efficiently, the purpose has been defeated. Sierra Nevada Brewing Co. (SNBC) understands this and prioritizes the importance of energy efficiency. There are a number of projects and installations around the brewery that improve their energy efficiency.

Heat Recovery

SNBC has installed numerous heat recovery applications throughout the brewing process to take advantage of heat transferring from one process to another. There are heat recovery units on the brew kettles, the boilers, each fuel cell unit, and there are plate heat exchangers throughout the brewery to transfer heat as product is cooled. Current boiler makeup water is roughly 15%. 85% of the condensate is recovered.

Other Efficiencies

Timers, ambient light sensors and motion sensors are placed where applicable – there are also instances where a motion is coupled with an ambient light sensor furthering the efficiency; ballasts and fixtures have been upgraded to be as efficient as possible; skylights have been installed throughout the plant to take advantage of natural lighting; software has been installed on computers to monitor energy usage and shut off computers not in use for a predetermined amount of time.

Monitoring

Currently being monitored in the system are both solar systems, all four fuel cells, utility purchased electricity and electricity sold back to the grid during overproduction periods. By tracking energy production and consumption on a real time basis, we are able to see spikes and dips in energy use and be better prepared for peak demand charges. In 2010, we have plans to start monitoring large load use points within the plant to help with load shedding during peak hours when electricity is the most expensive.

Solar

In December 2008, Sierra Nevada Brewing Co. completed one of the largest privately owned solar installations in the U.S. The solar system consists of two layouts – the parking structure array and the roof top array – and can produce a total of 1.9 MW of DC electricity with over 10,000 individual PV panels.

- The parking structure array was commissioned in September, 2007. It consists of 2,288, 225 watt SunPower panels and has a potential electricity output of 503 kW DC. This system is equipped with a sun tracking mechanism which follows the movements of the sun across the sky, adding 30% efficiency over a stationary system.
- The roof top array was commissioned in December 2008 and includes 7,688 185 watt Mitsubishi panels. The system is capable of providing an additional 1.42 Megawatts of DC electricity to the facility.
- SNBC has 28 panels on the company's daycare which offset the majority of electrical needs to run the center. There is also a 14 kW system that includes 76 panels installed on SNBC's rail transfer facility.

Fuel Cells

In 2005, Sierra Nevada was the first brewing operation in the world 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 electricity. The fuel cells run on natural gas and have the potential to be more closed loop by running on biogas generated at the Sierra Nevada (waste) water treatment facility. Sending the biogas to the fuel cells is currently a work in progress. The fuel cell installation provides roughly 60% of the total electrical needs for the facility and is made 15% more efficient with the installation of steam generating heat recovery units on each cell.

Biogas

SNBC has an onsite waste water treatment facility treating all brewing process water. The treatment process includes an anaerobic digester which produces a methane rich biogas. SNBC has installed equipment to collect the biogas for reuse. SNBC is currently utilizing the biogas in their boiler system and are working on using the gas in the fuel cells. Utilizing biogas generated onsite for virtually free reduces the amount of natural gas needed and lowers utility bills."

Sounds futuristic? Not at all. SNBC is no longer alone. Another brewery, New Belgium Brewing Company of Ft. Collins, Colorado, has also embraced "green technologies" in securing their energy needs.

These and similar technologies could be considered by Canadian brewers as well, given the local conditions, technological and financial (and financing) options and emerging governmental incentives. A food for thought!

8.3 Boiler plant

Generally, Canadian breweries use steam boilers as steam is the heat transfer medium of choice. One kg of steam at 3.0 bar g (at 143.6°C) contains 2,133 kJ of energy when condensing to water, whereas the energy available from 1 kg of water used, e.g., at 140°C and cooled down to 120°C in the heating process, is only 85.8 kJ.

Steam boilers of various types are used in larger breweries. Microbreweries or brew pubs tend to use steam generators capable of producing from a few hundred to 3,000 kg of steam per hour (75 kW to 2.5 MW). Larger breweries with a decentralized steam distribution system to provide steam locally can also use steam generators to advantage. Boiler design, maintenance and retrofit are specialized skills best left to expert help from reputable suppliers. Their advice should also be sought when contemplating engineering or operational changes to a system.

In Canadian breweries, the cost of fuel to run the boiler plant accounts for a significant portion of the total energy bill. Therefore, it is important – and profitable – to concentrate on ways to make the boiler operation and steam distribution more efficient and less costly.

About 23% to 25% of the total energy input in the fuel will be lost in the boiler operation: 4% typically from the boiler envelope, 18% in the flue gases and 3% in the form of Blowdown. The 75% to 77% of thermal energy is contained in the outgoing steam and represents the boiler's thermal efficiency.

8.3.1 Boilers

When trying to reduce gas or oil consumption, ***concentrate first on tuning up the process****. Only then, focus on reclaiming the waste heat from flue gas.*

Theoretically in combustion, the molecule of fuel is completely broken down to produce carbon dioxide (CO_2) and water vapour (H_2O). In practice, to ensure complete combustion of fuel, even the modern, well equipped combustion equipment must operate with excess air. Excess air has beneficial effect in speeding up mixing of fuel and air and provides all the fuel with the oxygen necessary for combustion. It also prevents situations where incompletely burned fuel would create potentially explosive conditions within the boiler.

Conversely, excess air wastes energy by carrying heat off up the stack. Hence, it is a fine line to walk between the combustion efficiency and safety in ensuring the only the minimum excess air is supplied to the burner.

Simple, direct method for calculating boiler efficiency:

1) Measure steam flow (lb or kg) over a set period, e.g., one hour. Use steam readings integrator if available.
2) Measure the flow of fuel over the same period, using the gas or oil integrator, or determining the mass of solid fuel used.
3) Convert both steam and fuel to identical energy unit, e.g., BTU or kJ
4) Calculate the efficiency , using the equation:

   Efficiency = (steam energy: fuel energy) x 100

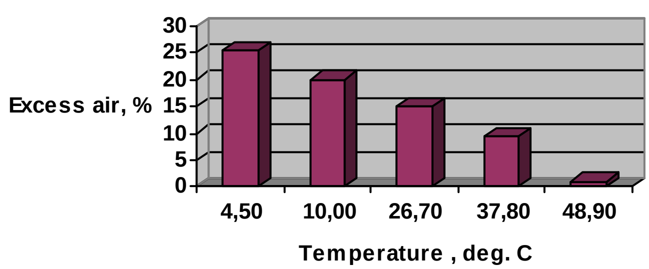
As our objective is to increase the boiler efficiency, it will be useful to review some of the main causes of the heat loss in boiler operations.

The magnitude of heat loss in flue gas depends on good fuel combustion and thus is controllable. Flue gas heat loss is minimized by proper burner set-up and maintenance, maximum air/fuel mixing, and control of combustion air rate and air temperature within an optimal range. Incomplete fuel combustion results in carbon monoxide (CO). Soot may form on the fire-side surfaces of the boiler, decreasing its efficiency further still. When oil is incompletely burned, it shows as smoke coming out of the stack.

Burners are always set to provide some amount of excess air in the flue gas. As excess air incurs a heat loss, it follows that reducing the oxygen level in the flue gas would reduce the loss.

It is important to realize that air-to-fuel ratio is a mass ratio, not a volume ratio. To control it means to control it on the basis of kg to kg. Thus the burner controls should compensate for seasonal temperature variations, and optimally, for day/night variations as well. Sophisticated systems compensate for air pressure as well. The effect of air temperature on excess air in flue gas can be dramatic:

Table 8.3.1.1 Effect of air temperature on excess air level:



Typically, 1% O_2 reduction corresponds to 2.5% efficiency gain.
Controlling the excess air is the most important tool an operator has for managing the energy efficiency and atmospheric emissions of a boiler system.

The variations in pressure and temperature can be corrected by sophisticated air a fuel control systems, which can be expensive. To avoid the expense, simpler systems with lower precision are employed to ensure larger margin of excess air. Since they cannot ensure optimum continuous operation, it pays to investigate the economics of a high-quality control system.

The carbon monoxide (CO) is a sensitive indicator of incomplete combustion. Its levels should be from zero to a few tens parts of million (ppm), rather than the environmental limit, usually 400 ppm. Each boilerhouse should have accurately calibrated analyzers for measuring O_2, CO and nitrogen oxides (NO_x).

Another controllable is the **blowdown heat loss**. It depends on the quality of make-up water, i.e., chiefly its dissolved solids content (TDS), the amount of contamination-free condensate returned to the boiler, and the blowdown regime employed. The blowdown control may be done by opening a valve manually for a period of time at certain intervals (based on experience or on boiler water analysis) or continually, or by automatic timer-operated valve, or automatically based on monitoring of TDS by, e.g., conductivity meter. Obviously, the latter method, with adequate safeguards, will minimize the blowdown heat loss.

An example what a poorly managed blowdown can cost:

Consider a 50,000 lb/h, 125-psig steam boiler. The blowdown water contains 330 Btu/lb. If a continuous blowdown system was set at the usual 5% of the maximum boiler rating, then the blowdown flow would be 2500 lb/h, containing 825,000 Btu. The heat loss is equivalent to 825 cu.ft. /h, or up to 168,000 m^3/y natural gas (at 300 d/y operation and \$0.45/m^3, worth about \$75,600.

8.3.2 Environmental impacts of boiler combustion:

Brief treatment of the topic is in section 7.0 of this *"Guide".* Also, the NRCan's brochure *"An energy efficiency and environmental primer for boilers and heaters"* guidebook treats the topic in detail. Nevertheless, a few things have to be mentioned here.

The brewery's boilerhouse faces a double challenge. One is economic – to get the best possible value out of its fuel budget. The other is environmental – to keep emissions as low as possible, to stay well within the legislated limits. Fortunately, the two objectives are intertwined.

Table 8.3.2.1 CCME* NOx emission guidelines for new boilers and heaters:

Input capacity	NOx emission limit, g/GJ** and (ppm at 3% O_2)***	
	10.5 to 105 GJ/h (10 – 100 million Btu/h)	Greater than 105 GJ/h (>100 million Btu/h)
Natural gas	26 (49.6)	40 (76.3)
Distillate oil	40 (72.3)	50 (90.4)
Residual oil with less than 0.35% nitrogen	90 (162.7)	90 (162.7)
Residual oil with more than 0.355% nitrogen	110 (198.9)	125 (226.0)

* Canadian Council of Ministers of the Environment
** g/GJ = grams of NO_x emitted per gigajoule of fuel input
*** ppm = parts per million by volume, corrected to 3% O_2 I the flue gas (10,000 ppm = 1%)

To correct ppm O_x to 3% O_2: NO_x at 3% O_2 = (NO_x measured x 17.9) : (20.9 –O_2)
where O_2 is oxygen measured in flue gas, dry basis

To convert ppm NO_x at 3% O_2 to g/GJ: for natural gas, g/GJ = ppm : 1.907
For fuel oil, g/GJ = ppm : 1.808

The guideline provides higher limits for equipment that can be shown to be highly efficient – therefore burning less fuel. Enforcement of the guideline is a provincial responsibility and provinces may enact stricter limits. Read the CCME Guideline to find out how it applies to boiler undergoing modifications or overhaul.

It is rather important to know what is involved when the brewery has older equipment:

Table 8.3.2.2 Typical NO_x emissions without NO_x control equipment in place:

Fuel & boiler type	Typical NO_x emissions, ppm at 3% O_2
Natural gas	
Fire tube	75 – 115
Packaged water tube	40 – 90
Field-erected water tube	45 - 105
No. 2 oil	
Fire tube	70 – 140
Packaged water tube	90 – 150
Field-erected water tube	40 – 115
No. 4 oil	
Packaged water tube	160 – 310
Field-erected water tube	140 – 190
No. 6 oil	
Packaged water tube	200 – 360
Field-erected water tube	190 – 330

The strategies for achieving compliance with NO_x regulations – well beyond the scope of this "Guide" – are described elsewhere – e.g., in *"An energy efficiency and environmental primer for boilers and heaters."*

Heat recovery in the boilerhouse:

Even with the well-adjusted burners, the exit temperature of the flue gas may range normally from 175°C (~ 350°F) to 260°C (~ 500°F). It presents the best opportunity for heat recovery. Heat exchangers for preheating boiler feedwater – called economizers – or combustion air (called air heaters) can be employed to increase overall boiler efficiency by 3-4%. With condensing economizers the overall boiler efficiency may exceed 90%. Application of heat pumps can increase the heat reclaim efficiency further still.

Heat may be also reclaimed from the blowdown that gets normally sewered. Installation of heat exchangers can reclaim the sensible heat for heating boiler make-up water and the like.

Case study: Preheating boiler combustion air with stack waste heat

A 300 HP natural gas boiler was drawing air from the outside that resulted in unnecessary fuel consumption to heat the combustion air. The boiler used 56,787 Therm per year and was operating at 82% efficiency. A high-quality heat recuperator could recover up to 60% of waste heat, or 6,133 Therm per year. At $0.95312 per Therm, the savings amounted to $5,846 annually.

For natural gas, the following formula is used in the calculations:

$$CS = EC \times (1 - \eta) \times RC; \text{ where:}$$

CS = cost savings, $/y

EC = energy consumed, Therm/y

η= boiler efficiency, %

RC = energy recoverable by recuperator, %

The installed cost of the recuperator was $19,980 (at the time), and the simple payback was 3.4 years. However, the payback time could be reduced significantly, should the operating time increase from larger production and more shifts.

Case study: Implementing periodic inspection and adjustment of combustion of a gas-fired boiler

The same 300 HP boiler used as an example in the Case study above used excess combustion air that showed as 6.2% oxygen in the flue gas and a temperature of $204^{o}C$.

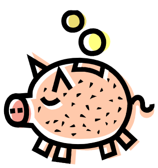
Optimally, the excess oxygen should read only 2%, which corresponds to 10% excess air. This could provide a possible fuel saving of 3%.

Using data from the above case study and a chart plotting excess air (%), stack temperature, fuel savings (%) and % O^{2} versus excess air, it is possible to calculate the savings.

Savings would amount to $1,083 annually (at the time). With a $750 purchase of a flue gas analyzer, the simple payback was 8.2 months.

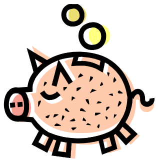
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Keep your boiler clean – remove the deposits on the fireside of the tubes. This fouling reduces heat transfer dramatically: a mere 0.03 inch (0.8 mm) thick soot layer reduces heat transfer by 9.5% and a 0.18 inch (4.5 mm) layer by 65%! The flue gas temperature rises as a result – and so does, on account of energy losses, the energy cost.
- Maintain the soot removal mechanisms in good condition (e.g., soot blower systems, brushes, manual lances...)
- Set up a chemical treatment program to reduce scaling and fouling of heating surfaces, and pumping resistance. A scale layer 1 mm thick will increase fuel usage by 2%.
- Analyze the boiler water regularly to verify effective water treatment and prevention of scale depositing.
- Keep unwanted air out: set up the boiler to achieve optimum combustion efficiency (air/fuel ratio). An insufficient fuel ratio will result in soot formation, decreasing heat transfer on the fireside of the boiler (if oil is used)
- Prevent ingress of extra air to the combustion chamber
- Check boiler efficiency regularly and maintain records. (A simple calculation involves converting the amount of fuel used in a given period and steam generated to energy units [kJ or Btu]. Boiler efficiency will be the ratio of the two.)

Housekeeping, no or low cost



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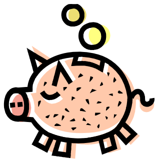
- Check flue gas oxygen and carbon monoxide levels regularly with a manual (chemical Orsat) or automatic flue gas analyzer. The oxygen levels should be in the following ranges:
    - Natural gas: 2.0% min. and 2.7% max.
    - Heavy fuel oil: 3.3% min. and 4.2% max.
    - Light oil: 2.3% min. and 3.5% max.
    - (NB: The above settings are typical for boilers without low excess air combustion equipment. In the other case, e.g., for natural gas, 1.7% minimum value can be achieved)
- Remember that a 10% reduction in excess oxygen will reduce the flue gas temperature by 2.5% and increase boiler efficiency by 1.5%!
- Keep blowdown levels and frequency to the absolute minimum, responding to regular monitoring of TDS levels
- Set up a maintenance program for descaling both sides of the heat transfer interfaces everywhere
- Monitor steam consumption and stagger loading to avoid demand surges
- In multiple boiler installations, size the use of boilers optimally to fit the production schedule, existing demand and calendar (day of the week, seasons)
- Maintain control setting to prevent overheating
- Maintain steam pressure to suit the demand; avoid excess pressure
- Attempt to stabilize heating demands by reviewing process demand scheduling, so as to minimize boiler load swigs and to maximize the boiler efficiencies. Attempt to maintain full-load boiler operation.
- Avoid dynamic operation – review brewhouse kettle boil control and steam valve operation
- Lower the steam pressure (or water temperature) to what is actually required by processes – suit the supply to the demand – do not oversupply (e.g., if no pasteurization is going on, scale down the steam pressure to only the brewhouse requirements,
- Choose low-pressure operation during non-production periods or deploy a smaller boiler only
- Compress the brewing schedule in the low production periods to avoid stops and starts of large boilers

Housekeeping, no or low cost



(Continued)

- In summer, block the boilers in by closing king valves: no heating is required and no steam is distributed, but keeping the boilers hot will considerably increase the life of firebrick lining and tubes
- Ensure proper de-aeration of boiler feedwater also by checking and maintaining the air vents.
- Regularly calibrate measuring equipment and instrumentation ad tune up the combustion control system.
- Regularly check all the control settings
- Regularly check and verify the boiler efficiency
- Regularly monitor and compare the boiler performance-related data to standards and targets
- Regularly apply routine ad preventive / predictive maintenance programs to the boiler and heat distribution / condensate collection systems
- Review whether in or in the vicinity of your brewery there are combustible by-products available (e.g., biogas form your anaerobic WWTP; or waste hydrogen, oxygen, carbon monoxide [CO], or hydrocarbon streams from a nearby factory) that you could utilize as a no-cost or low-cost boiler fuel supplements

Medium cost

- Collect blowdown to generate low-pressure steam for use in heating systems or for deaerators. Use other heat to preheat make-up water
- Consider fitting boilers with burners that will mix waste oil with regular boiler fuel to gain additional energy and reduce disposal costs
- Add/upgrade measuring, metering and monitoring equipment to the boiler and heat distribution systems, e.g., for fuel, steam, heating fluid, condensate and blowdown flows.
- Optimize the location of sensors; ensure that sensor and control devices are easily accessible for control and maintenance.
- Fit controls with locks, to prevent tampering ad unauthorized adjustments
- Relocate the combustion air intake to a location where the incoming air has the highest possible temperature year-round

Capital cost

- Consider instituting a metering and targeting (M&T) program to manage better the thermal energy usage throughout the brewery
- Consider the economics and means of capturing radiation and convection heat from the boiler shell for combustion air pre-heating. Evaluate the flue gas heat recovery system for preheating of feedwater and/or boiler air intake. A number of systems are commercially available. Remember that a 20^0C drop in flue gas exit temperature will improve boiler efficiency by 1%!
- Consider installing the latest types of heat-reclamation equipment – economizers and air heaters for flue gas and heat exchangers / heat pumps for boiler blowdown.
- Consider deploying heat cascading principle in the brewery, if not done already and where possible, where high-grade heat supplied from fuel is directed to the brewhouse (the process having the highest temperature requirement) and the exhaust heat is used in lower temperature applications, e.g., in the bottle washer.
- Consider investing in high-precision burner controls for continuous correct air-fuel ratio management
- Upgrade the fuel burner. E.g., consider employing the fuel direct injection (FDI) technology; a full-time FDI regenerative burner (FFR) reduces NO_x emissions by about 90% compared to ordinary regenerative burners. The compact FFR burner allows simplifications and downsizing, along with significant energy consumption reduction and short payback.
- Install a turbulator in fire-tube boiler.
- Install local high-efficiency boilers that respond rapidly to load demands
- Consider removing heat sinks when regular switching off boilers is necessary: if dense firebrick is used for lining the furnace, it needs to be installed in adequate thickness to limit the heat conductive losses. However, the large mass of the firebrick acts as a heat sink. It is expensive to heat up. New low-density ceramic fibre materials are used, often in combination with other refractory materials, to remove these heat sinks and provide superior thermal insulation
- Consider repositioning upgraded burners in the boiler furnace. A company in Québec did this. It improved furnace heat distribution and achieved natural gas savings at the same time.

8.4 Steam and condensate systems

This section is intertwined with the description of the boiler systems in 8.3. They should be read together.

Remember: loss of steam or loss of condensate = money down the drain!

The major factors in controlling the efficiency of steam distribution and condensate return are:

Optimum steam pressure: In a balance between capital cost and overall efficiency of the system, steam pressure should just meet the maximum required by the equipment in the system. High pressure results in leakage and flash steam losses; low pressure generates large surface heat losses during distribution and in the user equipment.

Pipework: The steam distribution system should be reviewed every few years for adequacy in light of changes in the brewery's position, future expansion plans, and changing technology and needs.

Often, with the passage of time, the steam distribution system is modified. Old equipment is scrapped and new equipment brought in. However, old existing but no longer used piping is seldom removed. The first step in any pipework rationalization is to remove redundant piping and then reduce the length of the piping in use as much as possible. The diameter of piping must be correctly sized to the use intended. Large diameter, oversized pipes that carry low volumes of steam may have heat losses larger than the process load. Undersized pipes have higher pressure requirements and higher leakage losses.

Careful attention must be given to a proper layout and location of drain points to ensure timely removal of condensate before it can cause problems.

The presence of condensate in steam pipes may cause water hammer, leading to increased maintenance, poor heat transfer and energy waste.

Insulation: The optimum insulation is a compromise between its cost and the cost of lost energy. The law of diminishing returns applies when more than the optimum insulation is contemplated. Doubling of the thickness of the insulation results in only a marginal reduction in heat losses. Heat loss that is prevented by insulation translates into significant fuel savings in the boilerhouse. Attention must be paid to regular inspections and maintenance of the insulated pipes – both steam and returning condensate – and their components, valves, expansion joints, etc. Ingress of water from the outside or from leaks negates the effect of insulation.

Insulation: (Continued)

The economic consequences of not having pipe insulation installed are shown in a case study in section 8.17 Maintenance.

Leakage:

(See the topic also under section 8.17 Maintenance)

The hissing sound one often hears in a brewery may also come from a steam leak.

How much it may cost, shows the attached table, where typical leaks in a 7-bar g system are related to the fuel so wasted:

Table 8.4.1 Steam leakage losses:

Leak size – diameter in mm	Steam loss – tonne/year	#2 fuel oil wasted – tonne/year
0.80	12	0.8
1.60	48	3.4
3.20	180	12.6
6.40 (1/4”)	732	51.2
9.50	1680	118.0

The cost of several leaks can be easily assessed, given the current rate the brewery pays for fuel.

Heat transfer:

Water condensate, air films and the presence of scale on the steam side of heat transfer equipment cause heat losses not readily apparent, yet significant.

As little as 1% by volume of air in steam can reduce the heat transfer efficiency by up to 50%!

1 mm of scale build-up can increase fuel consumption by 2%

Insidious, significant heat losses come from water condensate and air films, as well as from the presence of scale on the steam side of heat transfer equipment.

Steam traps:

Steam traps constitute the most common source of troubles if poorly selected, installed and maintained. Steam and condensate may be lost through steam traps. Condensate and air inadequately removed from the steam pipes and equipment reduces efficiency.

Condensate recovery:

Losses of condensate are literally money down the drain. If not returned to the boiler, about 20% of the original heat used to

Condensate recovery:
(Continued)

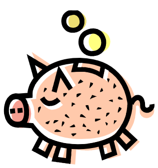
generate the steam may be lost. As well, costs increase for the purchase and treatment of make-up water and its heating. Additional energy losses occur in the form of flash steam that develops when the process pressure, under which the condensate is returned, is released in the condensate return tank. This is called open condensate return system.

Maximize hot condensate return!

Proper design of steam and condensate return system is important in order to eliminate water hammer, reduce losses and maintenance. A closed-loop system of condensate return delivers steam condensate under pressure to be re-boiled with practically no losses, thus requiring less steam to re-boil.

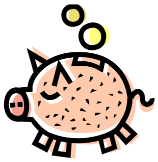
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Examine current plant piping drawings, if available, or walk through the facility and look for opportunities to rationalize and streamline the steam and condensate network. First, ensure that obsolete, unused or redundant piping can be isolated from the rest of the system. Then plan on removing the parts that are not required any more.
- Ensure efficient operation of the downstream steam and hot water using process equipment by proper production scheduling and maintenance.
- Attempt to operate the downstream steam ad hot water using equipment at capacity
- Shut the downstream steam or hot water using equipment when not needed.
- Shut the downstream steam and condensate branch system when not needed.
- Maintain good steam quality (i.e., maintain the program of regular water chemical treatment, blowdown regime and ensure proper function of feedwater de-aerating equipment and air vents on steam piping.)
- Repair, replace or add air vents (e.g., thermostatic air vents)
- Regularly check the integrity of the steam and condensate network (heating fluid supply ad return network) and associated equipment. Walk through the facility with appropriate detection equipment (e.g., ultrasonic detector, listening rods, pyrometer, and stethoscope) and look for and listen for steam leaks.
- Identify and repair steam and condensate leaks

Housekeeping, no or low cost



(Continued)

- Properly insulate steam and condensate return lines and components with efficient insulation at an economic thickness
- Add isolation where it is inadequate
- Inspect the insulation for waterlogging; locate the source of the moisture and correct the problem (e.g., leaking pipe)
- Replace or repair any missing and damaged insulation and/or isolation covering.
- Set up a steam trap maintenance program to ensure optimum performance, and reduce downtime of steam systems
- Review whether the steam & steam condensate recovery network (and heating coils ad other steam using equipment) has proper drainage; eliminate water hammer, and losses and damage that it generates

Medium cost

- Consider recovery of flash steam from condensate and consider using the recovered low-pressure steam elsewhere
- Consider recovery of heat from higher-pressure condensate
- Replace steam space heaters with infrared heaters for large areas (shipping docks, maintenance, etc.) to heat people and not the equipment
- (A brewer’s contributed suggestion:) Consider the separation of process and heating steam and condensate return systems so that heating loops can be isolated during non heating periods
- Consider using steam-powered condensate return pumps instead of electrically powered ones
- Collect all possible condensate (this should be as close to 90% as possible, or better)
- Decommission redundant steam and condensate return piping
- Shorten and/or simplify the existing steam and condensate return piping
- Overhaul steam pressure-reducing stations
- Institute a steam trap replacement program
- Replace incorrectly selected steam traps with the correct type for the service

Capital cost

- If used in pasteurizers and soakers, consider replacing live steam injection that loses the condensate from circulation, i.e., consumes de-mineralized make-up water and necessitates its heating and conversion into steam (and dilutes the caustic concentration in soaker baths), with heat exchangers
- Consider installing a closed-loop pressurized condensate return system
- Have a qualified contractor review, and if necessary redesign the steam and condensate network to optimize it. Re-pipe systems or relocate equipment to shorten pipe lengths where it makes sense.

8.5 Insulation

> *The key step: determine the economic thickness of insulation. It is the thickness, which provides the highest insulation for the lowest cost.*

Proper insulation helps to reduce greenhouse gas emissions. How? Except for nuclear power and hydro-electricity, energy is produced by burning fossil fuels. Insulating against heat loss (e.g., pasteurizer) reduces the amount of fuel needed to produce the heat – and thus the emissions. The reduction may take place locally or, in case of electricity, upstream at the generating station.

We insulate process equipment, ducts, piping and buildings to:

- Prevent heat gains and losses
- Maintain consistent process temperatures
- Prevent burns (and frostbite) to employees
- Prevent condensation from forming on cold equipment surfaces; and
- Maintaining comfortable working environments around hot or cold process equipment

Thermal insulation deteriorates over time. A re-evaluation of long-established systems may show that the insulation is inadequate or damaged. For larger breweries, an investment in an infrared thermograph (video camera) may pay for itself in a short time. Alternately, a thermography consultant may help in discovering areas in need of repair or additional insulation or air leakage control. The benefits of upgrading or increasing insulation on process equipment and piping are clear: since the installation and initial insulation of equipment in most Canadian breweries some years ago, the fuel prices skyrocketed.

Insulation that depends on air-filled voids to function effectively must be kept dry. Exposure to moisture, particularly in the case of loose-fibre or open-cell foam insulation type, causes the displacement of insulating air by moisture/water ingress (e.g., leaking steam or condensate pipes). Effective cladding of the insulation is just as important as selecting the most effective type of insulation and installing an economic thickness. Waterproofing is therefore an integral part of any insulating job. For high-temperature applications, chose a vapour-permeable covering that will allow moisture to pass outwards.

> *Base the choice of insulation material on:*
> - *Halocarbons-free*
> - *Flammability/resilience*
> - *Performance/ Price*

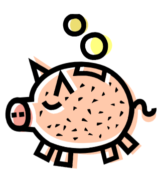
> *Water-saturated insulation transfers heat 15-20 times faster than when dry!*

Choose appropriate types of jacketing/cladding with sealed joints, and where the potential for mechanical damage is a factor, consider using insulation that is more resilient and has mechanical protection, or can be suitably protected (barriers, bulwarks, shields, bridges, etc.), to minimize chances of damage.

See also the topic of insulation mentioned under section 8.17 Maintenance.

Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Inspect the condition of process insulation regularly (include it in the PM schedule)
- Repair damaged insulation on pipes and vessels with cold or hot media without delays

Medium cost

- Insulate non-insulated pipe and ductwork
- Insulate non-insulated-yet equipment
- Upgrade existing insulation levels; add insulation to reach recommended thickness
- Insulate major non-insulated equipment/process areas
- Hire a thermography consultant to discover areas in need of (additional) insulation or air leakage control
- Improve insulation of hot water tanks

Capital cost

- Replace fiberglass insulation with closed-cell insulation I areas where condensation or wetness may permeate the fiberglass one
- Replace refractory firebrick with ceramic pyrobloc insulation in boiler furnaces
- Add insulation / exterior cladding to brewery buildings, roofs, crawl spaces, etc.

8.6 Refrigeration and cooling systems, and heat pumps

8.6.1 Refrigeration and cooling systems

It is commonly found that refrigeration systems in service are using 20% more energy than they should!

In a typical brewery in Canada, over 30% of electric power is consumed by refrigerating and cooling systems. Optimizing their function represents a major energy conservation opportunity.

To examine energy efficiency opportunities for a refrigeration system, it is the best to start with an assessment of the local temperatures, process requirements, refrigeration equipment and systems to identify areas of waste and the improvement opportunities. In refrigeration there are only a few basic ways to save energy revolving around these questions:

- Can we do away with some refrigeration needs (even temporarily, based on seasons)?
- Can we remove and/or reduce some of the refrigeration loads?
- Can we raise the refrigeration temperatures?
- Can we improve the operation of the refrigeration plant?
- Can we reclaim waste heat from the refrigeration plant?

Most brewery stationary engineers are well trained in the operation and maintenance of a boiler plant, but may be less so in a refrigeration plant. This operation may be operating below the potential performance level for the following reasons:

- Stationary engineers and operators may lack training in refrigeration efficiency.
- Refrigeration plants are relatively complex.
- Little or no appreciation of the potential for savings and their magnitude.
- A lack of defined performance criteria.
- Fault diagnosis is complex and time-consuming.

Savings opportunities arise from effectively controlling the factors that affect refrigeration efficiency and thereby cost.

In evaluating costs, more than the compressor efficiency should be measured. (In the evaluation of compressor efficiency, its coefficient of performance [COP] is used. This is the ratio of cooling achieved to power used). It is advantageous to measure the entire system's efficiency (SCOP), which also includes power to all the auxiliary equipment such as evaporator fans and pumps, condenser fans and pumps, oil pumps, secondary refrigerant distribution pumps and fans and defrost heaters.

Factors affecting refrigeration efficiency include:

Cooling loads:

The higher the load, the more cooling is needed, causing operating costs to rise. Part load operation is the most frequent cause of poor refrigeration plant efficiency. Perhaps for only three months of the year the plant operates at or close to the nominal design point. For the rest of the year, lower ambient temperatures allow lower condensing temperatures. The reduced loads alter the required compressor capacity. The cooling load has a major influence on the SCOP. Over-cooling of beer or spaces uses massive amounts of energy.

Compressor efficiency:

High efficiency can be maintained by using the best compressors suited for duty at any given time, by avoiding part-loads and by good compressor maintenance.

Evaporating temperature:

Raising the evaporating temperature increases COP and lowers the running costs: raising the evaporating temperature by 1 ^{o}C reduces costs by 2% to 4%. Higher evaporating temperatures can be achieved by good controls and by taking good care of the evaporating surfaces (avoidance of fouling, superheating, blockages and poor heat transfer).

Condensing temperature:

Lowering the condensing temperature reduces the running costs to the same extent as above. Lowering the condensing temperature by 1^{o}C reduces operating costs by 2% to 4%. Lower condensing temperatures can be achieved by good controls and by taking good care of the evaporating surfaces (avoidance of fouling, superheating, blockages and poor heat transfer). See the brewer-contributed note on incondensables under 9.5.

Auxiliary power:

Auxiliary power can account for 25% of the total power consumed by the refrigeration plant and more when the plant is operating at part-load. The auxiliary equipment should not be run excessively; good controls are required. Analyzing the annual cost of refrigeration improves understanding of the effects of poor operation and maintenance. Various cooling demands should be examined and costs allocated to the loads to determine major consumers. Controlling these major loads should be a priority.

As pointed out above, cooling loads should be kept to a minimum. Brewers distinguish between process cooling loads and auxiliary cooling loads.

Among the process cooling loads, sensible cooling (e.g., beer and glycol cooling), latent cooling (e.g., vapour condensation) and reactive heat removal (e.g., metabolic heat of fermentation, yeast autolysis) all take place.

Common cooling faults include:

- cooling from too high a temperature (e.g., pasteurizer beer exit temperature may be too high, which, incidentally, may also negatively affect flavour)
- over-cooling (e.g., hop storage, beer in storage tanks, cellar space)
- simultaneous heating and cooling (e.g., poor setting of heating and cooling controls
- in air conditioning, poor control of flow rates and temperatures in process beer heat exchangers)

The last point can be illustrated by using incoming cold water to cool wort. The wort is then trim-cooled with refrigerated glycol. In winter, the water may be cold enough to reduce the use of the trimming. Yet, for expediency, no adjustments to the trim chiller have been made. Instead, the water flow is throttled down and energy is wasted.

Auxiliary cooling loads include inadequate or waterlogged pipe and vessel insulation, warmer air infiltration, lighting, fans and pumps in cold spaces, people, lift trucks, etc. Since many auxiliary loads are “paid for twice” (e.g., lights and fans consume power and generate heat that must be removed by refrigeration, also using power), their control is as important as, and sometimes more important than controlling process loads.

Open cellar doors constitute a major portion of the auxiliary load. In cellars, controlled lighting by use of motion detectors, will keep the lights off as much as possible. As well, excessive use of fan power in cold areas and excessive use of pump power for circulating refrigerants and chilled water should be avoided by using such techniques as variable speed controls, flow controls, off/on switches, sequence controls, flow and pressure controls and so on.

Inadequate or excessive defrosting of the evaporators is also common. Defrosting should be stopped by using appropriate controls as soon as the ice has been removed. If not, heat is generated and has to be removed by refrigeration, a “paid for twice” case again.

In evaluating individual cooling loads, in many cases tests and analysis of options may need to be carried out to find optimum settings and solutions. Sometimes a small change of parameters may have a significant effect:

- A 1^{o}C increase in condensing temperature will increase costs by 2% to 4%.
- A 1^{o}C reduction in evaporating temperature will increase costs by 2% to 4%.
- Gas by-passing expansion valves may add 30% or more to your costs.
- Incorrect control of compressors may increase costs 20% or more.
- Poor control of auxiliary equipment can increase costs by 20% or more.
- Both gains and losses are cumulative.

Brewery operators should guard against the loss of refrigerant to avoid risk to health, safety and operability of the plant, risk to the environment, high refrigerant replacement costs, poor performance, and excessive refrigeration plant operating costs.

Case study: Refrigeration fault diagnosis system

A one million hectolitre-per year brewery capitalized on resident expertise and, with the aid of a consulting firm, developed and installed a Refrigeration Fault Diagnosis Expert System to evaluate refrigeration plant status and to advise on appropriate remedial action when there is a fault. An investment of $36,000 for the purchase of a computer, development of software, customization and operator training (dated costs) brought in savings that allowed the brewery to recoup its investment in eight months, during the training phase.

Savings resulted from reducing electricity consumption by 29.5%. The system's several modules monitor key measurements and data, calculate coefficient of performances (COP), analyze faults and recommend preferred actions for establishing the best combination of cooling equipment packages and loads to meet current cooling duty, given the ambient temperature.

Case study:

A brewer-contributed case study: **Install new primary compressor**

Currently, two 125 hp reciprocating, one 450 hp screw, and one 700 hp screw ammonia compressor serve the facility. During the two months of summer monitoring, one of the two screws operated at all times, with one reciprocating compressor supplementing.

The existing Mycom screw compressors had four major inefficiencies:

• The compressors are equipped with a 3.6 internal compression volume ratio (VI). This ratio is mismatched to the average operating conditions, which call for a lower ratio. The compressors overcompress most of the time, reducing efficiency.

• The compressors utilize standard slide valve capacity control, which is inefficient. When fully unloaded, the compressors still draw nearly 50% input power. This poor part load performance reduces efficiency.

• There is some question as to the minimum allowable discharge pressure the screw compressors can operate at. The Mycom rating software indicates a minimum around 120 psig. Lubrication or oil separator performance is often the limitation. This elevated discharge pressure reduces efficiency.

• The 450 hp TECO motor is rated at 94.0% efficiency, while the 700 hp Toshiba is rated at 95% efficiency. If they have been rebuilt, it is feasible that current efficiencies are even lower. Efficiencies over 96% are available for modern premium motors.

This measure recommended installation of a new compressor package to minimize or eliminate these inefficiencies. The new compressor can have:

1) a more appropriate fixed VI,
2) a manually-adjustable VI, or
3) an automatic VI.

It can be equipped with VFD control for improved part load operation, and can be configured for discharge pressure as low as 90 psig. Finally, a premium efficiency motor can be installed on the package.

Case study:

A brewer-contributed case study: **Evaporator fan cycling or 2-speed control**

Although many of the evaporator coils are managed by the plant PLC system, evaporator fans operate non-stop except during defrost. All Niagara coils have 2-speed fan motors, although most were set for high speed and cannot be automatically switched between low and high.

This measure includes pulling control of all remaining evaporator coils into the PLC and implementing a fan cycling strategy (or 2-speed in the case of the Niagaras). This may require additional space temperature probes.

Case study:

A brewer-contributed case study: **Condenser fan VFDs, reduced discharge, & optimum algorithms.**

Currently, one of four evaporative condensers utilizes VFD control. Although this provides some savings, the mix of discrete (cycling) and analog (speed) control makes for challenging control algorithms.

A staggered condenser strategy stages capacity from 120 psig up to 150 psig. Finally, the strategy turns fans on before pumps, resulting in stages of dry condenser operation. This is extremely inefficient. This measure includes several major upgrades:

- Install VFD control on all remaining condenser fans.
- Implement optimized pump and fan VFD strategies, including wet operation and simultaneous fan speed control. In addition, implement a wet bulb approach strategy to best match condenser capacity to engine room heat rejection.
- Reduce minimum discharge pressure to 90 psig. (Note that this may require some attention to the existing screw compressors if it is implemented. Previous short-term experiments have shown that operation at reduced discharge may be possible).

8.6.2 Industrial heat pumps

Industrial heat pumps or IHP, are process devices that use a low grade heat (such as waste process heat, or water or ground heat) as the heat source and deliver this heat at higher temperatures for heating or preheating of an industrial process. Some IHP can also work in reverse, as chillers, dissipating process heat as well. The use of this relatively new technology – which improves energy efficiency and contributes to reducing primary energy consumption – should be investigated by a brewery reviewing its heating and refrigeration needs.

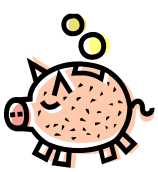
Case study: Waste heat recovery with a heat pump

A Canadian Maritime brewery installed a heat pump system to recover hot water for boiler feed and brewing makeup. The system has four major components: an ammonia condenser, a water pre-heater, the heat pump and water storage tanks.

The ammonia condenser is a shell and tube heat exchanger, which uses water to cool ammonia gas from existing refrigeration equipment. Heat recovered is then used twice – first to preheat the boiler feed water, then as a source of energy for a high temperature heat pump. As per design, the use of the heat pumps allows process water to heat to a temperature well above the level at which the heat is recovered from the refrigeration system. A hot water storage tank provides a buffer between the waste heat supply and hot water demand in the brewery. The use of low-cost waste heat reduces fuel consumption by $40,000 to $50,000 a year. However, the practical experience has brought out a lesson: do the design calculations carefully. The heat pump portion of this system was decommissioned due to higher operating costs of the compressor. Still, the ammonia condenser portion is used to pre-heat the boiler feed water.

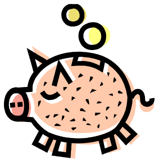
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Look up also items under section 8.2.1.
- Operators may not understand refrigeration efficiency issues – educate and train them first
- Operation and maintenance issues need to be constantly addressed; an inefficient operating mode may be more convenient to the operator
- Review your refrigeration plant regimen frequently as process requirements and ambient weather conditions change
- Implement good housekeeping practices:
- Keep the doors to refrigerated areas closed
- Separate the cold areas from the rest of the brewery by installing doors, plastic curtains, rubber swing doors, etc.

Housekeeping, no or low cost



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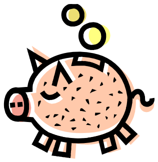
- In refrigerated rooms, use as little water as possible (remember that one gallon of water needs a ton of refrigeration of energy to evaporate; channel tank flushings etc. directly to the drain, do not let them spill onto the floor where they have to be hosed down)
- Eliminate ingress of moisture into the cooled space (from ambient air and from water hoses)
- Use cold cleaning-in-place (CIP) in refrigerated rooms whenever possible. Talk to your cleaning materials supplier about a suitable cleaner
- Review electric power tariffs and schedule the running of the refrigeration plant to avoid adding to the peak demand periods or set maximum cooling duties for night time
- Ensure that controls for defrosting are set properly and review the setting frequently, e.g., monthly, to take account of changing ambient conditions
- Ensure that defrosting operates only when necessary and for as short a period as necessary
- Review your system controls and correctly set points for evaporating and condensing temperatures
- Regularly measure the compressor COP and the overall SCOP, which includes auxiliary equipment to control the operation
- If water for condensers is supplied from cooling towers, ensure they are effectively maintained (fans, pumps, fouling, etc.) to obtain the lowest water temperature possible
- Check buildup of non-condensable gases and air on a regular basis to ensure the plant operates at high COP
- Check for the correct head pressure control settings
- Check for the correct levels of refrigerant in the system for optimum performance; eliminate leaks
- (A brewer's contributed suggestion:) Consider implementing an oil inventory management program to track the amount of oil added and drained from the system.
- (A brewer's contributed suggestion:) Try to ensure that pressure drop across oil separator does not exceed 4 psi – anything above this indicates oil carryover
- Adjust the cooling plant's evaporation temperature to about –6^{o}C to 8^{o}C, to cool beer to about –2^{o}C. Often the evaporation temperature is set unnecessarily lower
- Review the state of your instrumentation. Ensure that instruments read correctly and sensors are not affected by, e.g., ice formation; cross-check all values where possible

Housekeeping, no or low cost



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- Use a structured approach to find and correct faults, using the two basic methods: performance testing, and monitoring and targeting
- Install de-stratification ceiling fans in the cellars
- A regular testing program should be established so problems are quickly identified
- Review your maintenance program to avoid fouling, flow blockages, and to ensure good maintenance of pumps, fans and lights, etc.

Medium cost

- Determine annual costs as the basis for improvement decisions by installing electricity meters covering relevant areas:
  - compressors
  - main auxiliaries (fans and pumps for condenser, evaporator and secondary refrigerant-air distributing)
  - other (secondary) auxiliary equipment (defrosters in cold rooms, lighting)
- Consider installing an automatic purge system for air and non-condensable gases
- Sequence compressors on the basis of their loads and respective efficiencies
- Correct sequencing is most important in the case of part-loads. Ensure that only one compressor operates at part-load. If a choice of compressors exists for part-load operation, use a reciprocating compressor instead of a screw or centrifugal compressor, which has poor part-load performance
- Avoid the use of compressor capacity control systems, which throttle the inlet gas flow, raise the discharge pressure or use hot gas bypass
- Install an automatic suction pressure control system to modulate the suction pressure in line with production requirements to yield savings
- Segregate refrigeration systems according to temperature; optimize the thermodynamic balance of the refrigeration cycle to dedicate equipment to the minimum required conditions for each process
- Use low ambient temperatures to provide free cooling to suitable loads during winter and shoulder seasons
- Consider installing a thermosiphon (closed loop system) on ammonia cooling compressors

Medium cost

(Continued)

- Replace inadequate doors to cold areas; provide door closers to keep warmer air out
- Install traps to remove oil and water from the ammonia (contaminants in the ammonia raise the boiling point) – and (a brewer's contributed suggestion:) ensure routine draining of oil from refrigeration systems, especially on process equipment

Capital cost

- Replace compressors with the most efficient type available when justified
- If a number of evaporators in an integrated system are operating at pressures considerably higher than the suction line pressure, consider installing a separate system to enable running a portion of the load at higher operational suction line pressure and, therefore, higher COP (dual pressure ammonia system)
- Consider thermal storage – i.e., coolant storage (using ice tanks, eutectic salts or supercooled secondary refrigerant) to maximize the use of night-rate power. This will also reduce the requirement for additional chiller capacity if increased cooling demand is needed
- Evaluate the utilization of ammonia de-superheating heat recovery for preheating and reducing the cost of cooling in the condenser or cooling tower
- Evaluate absorption cooling if excess heat is available. This technology provides refrigeration without electricity input
- Evaluate installing a combustion engine-driven chiller unit as it provides a less expensive energy input and has a better part-load efficiency than electrical motors and affords heat recovery from the engine jacket and exhaust
- Consider installing split suction for high- and low-temperature requirements
- Consider replacing shell and tube exchangers with high efficiency plate heat exchangers

8.7 Compressed air

> In poorly managed systems, the true cost of electricity used to produce compressed air may approach $1.00/kWh!

***Compressed air is the most expensive utility in a brewery*:** The brewing industry uses a great deal of compressed air for production process control purposes. It is a safe and convenient form of energy, frequently taken for granted and overlooked as a possible savings option. About 8% of total brewery electricity supply is used for compressed air generation, if the plant does not operate a wastewater treatment plant.

Most brewery employees view compressed air almost as a free and convenient resource and are not aware that compressed air is the most expensive utility in the plant. Compressed air is an inefficient medium as some 85% of the electrical energy used to produce it is converted into heat and only the remainder to pneumatic energy. Yet, often it receives little attention. A brewery typically requires approximately 8% of the total brewery electricity supply for compressed air generation, much more if it operates an aerobic wastewater treatment facility.

Compressed air is widely used in a brewery in process control. It produces a linear actuation for positioning kegs, bottles and cans onto the filling heads. It produces a linear or rotary motion to actuate and accurately position control valves. It is used as a means of propelling solids (spent grains) or pushing liquid from vessels where pumping is not desirable or is difficult. Further uses include operation of portable agitators and hand tools. It is also used for facilitation of confined-space and hazardous atmosphere entry, etc. Undesirable uses of compressed are the wasteful, unsafe and unhealthy practice of blowing dust or debris off surfaces and using it for cooling duties.

The brewery operation that requires the highest pressure should determine the pressure of compressed air in the system. It is very expensive to produce more pressure than needed. For example, if only 5 bar g pressure is needed but 8 bar g pressure is generated in the system, the costs are unnecessarily 40% higher.

Reciprocating piston compressors are the most prevalent type. There are several variations: double-acting; lubricated; non-lubricated; single cylinder; or multiple-cylinder, two-stage machines. Other types are screw compressors, rotary vane or rotary lobe machines. The latter, also known as “Roots Blower”, is designed for low-pressure ratio duties to a maximum of 2 bar g.

Leaks are a major source of inefficiency, typically accounting for about 70% of the total wastage but as high as half of the site’s consumption. By the time the compressed air reaches the end user, it can cost about $1.00 per kWh!

The following table illustrates the results of leakages through holes of various diameters in a 600 kPa g system, using electric power at $0.07 per kWh.

Table 8.7.1 Cost of compressed air leaks

Hole diameter	Air leakage	Cost $/month
1 mm	**1 L/s**	**14**
3 mm	**10 L/s**	**150**
5 mm	**27 L/s**	**417**
10 mm	**105 L/s**	**1655**

Leakage does not just waste energy, it also affects operating costs. As leakage increases, system pressure drops, air-using equipment functions less efficiently and production may be affected. The costly remedy is to increase the generating pressure to compensate for these losses.

Long-term costs of compressed air generation are typically 75% electric energy, 15% capital and 10% maintenance. Simple, cost-effective measures can save 30% of electric power costs. Consequently, the effort to make a system energy-efficient is highly effective. The work should include examinations of compressed air generation, treatment, control, distribution and end use.

Typically, only a little more than 20% of electrical energy used to retrieve and compress air is converted into mechanical energy of the compressed air.

Compressed air is, mistakenly, often considered "free" by those using it, because free air is being used from the atmosphere. The electrical cost of compressed air may run to 70% or more of the total annual system's operating costs, while maintenance and depreciation may take 15-20% each. Therefore, it is clear that compressed air is one technology where energy efficiency improvements are directly related to financial savings. On average, the savings may be found in fixing:

- Leaks – 25%
- Poor applications – 20%
- Air lost in drainage systems – 5%
- Artificial demand – 15%

Artificial demand is the extra compressed air consumption when operating the system at higher pressures than necessary.

What remains is the net useful compressed air usage – only 35%! The above breakdown of losses varies with the company involved. In some systems, the leaks alone may account for 60%!

The compressed air leak losses can be calculated during a no-consumption period, using the formula, $V_L = [V_C \times t] : T$, where V_L is the volume of leak loss, V_C the capacity of the compressor at full load in m^3/min, **t** = time in seconds of full-load compressor operation (i.e., total full-load measuring time) and **T** = total measured, elapsed time.

The rule of thumb is that leaks should not be higher than 5%.

Our investigations should concentrate on the above areas. It should start with a quick, simple scan of the system. Its purpose is to optimize the existing system, leading to savings in energy and money. Each part of the system should be investigated for possible improvements and saving options. However, for best results, do not just consider it as a sum of individual components such as compressors, dryers, filters, coolers and the auxiliary equipment.

> *Simple, cost-effective measures can save 30-50% of generating electric power costs.*

Take an overall view and think dynamically in terms of pressures versus volumes, rates of change in pressure etc., to optimize the system effectively. This approach will result in a considered, thoughtful audit of the compressed air system, to include:

- Analyzing demand and matching capacity to demand
- Controlling peak demand events
- Correcting poor applications and waste in using compressed air
- Identifying and correcting leaks
- Controlling and managing the entire system
- Optimizing the maintenance program
- Sensitizing users to correct practices and savings opportunities
- Monitoring results, performance and costs of the compressed air system's operations

Together with a brief description of the various issues, we list some **remedial EMOs**, and indicate whether they would likely be in the category of housekeeping items of zero or little cost (**$**), medium cost (**$$**) or retrofit high-cost capital items (**$$$**).

Analyze the demand

- Identify critical users and analyze their needs regarding compressed air pressure, volumetric flow, frequency of use and duration of the usage events. That will help in designing eventually custom-fitted solutions, and minimize affecting other users in the system ($)

Control peak demand

- Provide adequate compressed air storage capacity to reduce cycling; consider installing additional compressed air tanks ($)
- Consider replacing part of the air distribution network with large-diameter piping to stabilize air supply and enable reduction of air pressure ($$ - $$$)

Correct poor applications	➢ Replace vacuum generators using compressed air, pneumatic motors, dusting by blowing compressed air, and open blowing, with other equipment giving the same results but at lower costs ($ - $$). If need be, install a low-pressure blower for the job
Eliminate waste	➢ Generate compressed air at the lowest possible pressure suitable for the task ($) ➢ Never generate at too high a pressure only to reduce it to a lower operating pressure later ($) ➢ Do not compensate with higher pressure for poorly maintained air tools or undersized air distribution lines ($) ➢ Consider using high-efficiency blow nozzles (reducing air consumption by at least 50%) ($) ➢ Consider using a different nozzle type and configuration when blowing off water after pasteurization ($ - $$) ➢ Minimize losses of compressed air in various pieces of measuring and controlling equipment using it: install section valves ($$) ➢ Consider dual pressure control for off-shift operation ($$) ➢ Switch off compressors when not needed ($) – include the weekends if possible
Eliminate leaks *Remember: A leakage reduction program must be ongoing to be effective!*	➢ Think of compressed air as you would water: stop the leaks at once ($) ➢ Use the listening method after normal working hours ($) ➢ Invest in an ultrasound listening device to identify leaks (e.g., Ultraprobe 2000™) ($) ➢ Consider purchasing a compressed air leak tester to detect pressure drops because of leaks and to measure the compressor capacity ($$) ➢ Consider implementing an automatic leak-measuring process, to be done on weekends, through a computerized control, regulation and monitoring system and installation of enough section valves
Manage system	➢ Require users to justify using the compressed air ($) ➢ Institute metering of the usage by end-point users ($) ➢ Make users fiscally accountable for the compressed air usage ($)

Manage system *(Continued)*

- Consider installing "load shaping" – a dedicated demand management system to handle peaks without affecting the pressure levels, starting additional compressors needlessly, or leaving excess compressors running "just in case" ($$$)
- Use the central control, regulation and monitoring system to start/stop the compressors at pre-determined times during the week ($$$). (Note: one such program is XCEED™ Compressed Air Management System by Honeywell.)

Maintain system

- Uncontrolled compressed air quality can lead to production downtime. Implement a regular maintenance, inspection and preventive maintenance program for the system's components. Include also the control and monitoring equipment in the program ($)

Train operators

- In order to achieve operational savings and quality improvements, users and operators must understand the system and be aware of its operating costs ($)
- Delegate responsibility for ensuring that the compressed air system has no leaks ($)
- Request operators to mark leaks manually as soon as discovered for maintenance to fix ($)

Monitor performance

- Install both electricity and air flow meters (vortex), to allow energy monitoring ($$)
- Monthly, monitor, e.g.:
  - kWh/total number of labour hours in production
  - kWh/m^3 (i.e., compressor efficiency)
  - m^3/total number of labour hours in production
- In addition, do likewise in terms of dollar costs

Case study: Lowering air pressure in compressors

A 60 HP air compressor was being operated at 760 kPa (110 psi), although the maximum pressure required from any process machinery was just 620 kPa (90 psi). Consequently, by a simple adjustment of the pressure regulator, the compressor discharge air pressure could be lowered to 655 kPa (95 psi). The horsepower output would be reduced by 7.5%.

Lowering the operating pressure of a compressor reduces its load and operating brake horsepower. Using an appropriate chart to plot the initial and lowered discharge pressures, an approximate decrease (in %) of the brake horsepower can be determined.

Savings are calculated using the formula:

$$CS = (HP : \eta) \times LF \times H \times S \times WHP \times CF; \text{ where}$$

- CS = anticipated cost savings for the compressor, $/y
- HP = (nominal) horsepower of the compressor (i.e., 60 HP)
- η = efficiency of the electric motor driving the compressor, %
- S = estimated horsepower reduction (i.e., 7.5%)
- H = annual operating time in hours
- LF = average partial load (e.g., 0.6)
- WHP = conversion factor (0.7459 kW/HP)
- CF = electricity consumption cost, $/kWh

The simple payback on savings of $480 per annum (at the time) was immediate.

Case study: Repairing compressed air leaks

One significant air leak (6 mm diameter) and three small ones (each 2 mm diameter) were found in the compressed air system, through a plant inspection during a period of no production. The total loss was 137 kg air/h. The mass flow out of a hole is calculated using Fliegner's formula:

$$m = 1915.2 \times k \times A \times P \times (T + 460)^{-0.5}; \text{ where}$$

- m = mass flow rate
- k = nozzle coefficient (e.g., 0.65)
- A = area of the hole
- P = pressure in the line at the hole
- T = temperature of the air in the line

Savings are calculated using the formula:

$$CS = P \times L \times HR \times LF \times CF; \text{ where:}$$

- CS = cost savings, $/y
- P = energy required to raise air to pressure, kWh/kg
- L = total leak rate, kg/h
- HR = yearly operating time of the compressed air system, h/y
- LF = estimated partial load factor (e.g., 0.6)
- CF = electricity consumption cost, $/kWh

Fixing the leaks (even temporarily with a clamp over the leak) realized annual savings of $1,360 (at the time) and a simple payback of 12 days.

Case study: Redirecting air compressor intake to use outside air

A 60 HP air compressor drew air from the engine room where the temperature was 29^{o}C. The annual average outside air temperature was 10.5^{o}C. Redirecting the air intake to the outside (north side of the building) resulted in drawing cooler and therefore denser air. The compressor worked less to obtain a given pressure increase as less reduction of volume of air was required. The power savings amounted to 7.1%.

The calculation to reduce compressor work from a change in inlet air temperature involves the following formula:

$$WR = (WI - WO) : WI = (TI - TO) : (TI + 460); \text{ where:}$$

WR = fractional reduction of compressor work

WI = compressor work with indoor inlet

WO = compressor work with outdoor inlet

TI = annual average indoor temperature, ^{o}F

TO = annual average outdoor temperature, ^{o}F

Savings from using the cooler intake are calculated using the formula:

$$CS = HP \times (1 : \eta) \times LF \times H \times WHP \times CF \times WR; \text{ where:}$$

CS = anticipated cost savings, $/y

HP = horsepower for the operating compressor, HP

η = efficiency of the compressor motor, %

LF = average partial load factor (e.g., 0.6)

H = annual operating time, h

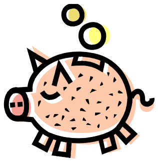
WHP = conversion factor, 0.7459 kW/HP

CF = electricity consumption cost, $/kWh

The annual savings amounted to $445 (at the time). With the cost of installation (PVC schedule 40 pipe and some rolled fiberglass insulation), the simple payback was 10 months.

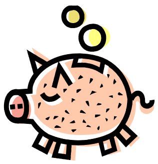
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Maintain air filters
- Eliminate redundant couplings and hoses as potential sources of leaks
- Remove obsolete compressed air distribution piping (to reduce pressure loss, leaks and maintenance costs)
- When reciprocating and screw compressors are used in parallel, always maintain screw compressors at full load; when partial loads are required, shut down the screw compressor and use the reciprocating compressor instead
- Avoid using compressed air when low-pressure blower air will do the job as well
- Ensure the system is dry – ensure that drainage slopes, drainage points and take-off points (always on top) prevent internal corrosion of the piping
- Review all operations where compressed air power is being used and develop a list of alternative ways
- Review the compressed air system and air uses annually – develop a checklist to simplify the task
- Keep all air tools, connectors, and hoses in good repair
- Commit to a brewery-wide awareness program
- Draw intake air for both compressing and compressor cooling (if air-cooled) from the coolest location outside, probably by direct ducting of fresh intake air from the outside
- In air-cooled compressors, discharge heated air outdoors during the summer and use indoors for space heating during winter
- Check that the system being operated is not faulty (if it requires higher than design pressure)
- Check that there are no problems with piping causing system pressure drops
- Ensure that the system is dry: correct slopes of the piping, drainage points, and take-off points (always on top of piping).
- Beware of piping corrosion; it can lead to pitting and leaks
- Implement a regular system maintenance and inspection program
- Invest in a leak detector/air leak tester to measure total volumetric leakage throughout the compressed air system and also the compressor capacity
- Switch off compressors when production is down. If compressed air is needed for instrumentation, consider

Housekeeping, no or low cost



(Continued)

installing a separate compressor for this function; it will save wear on the main compressors as well

- When reciprocating compressors and screw compressors are used in parallel, always maintain screw compressors at full load. When partial loads are required, use the reciprocating compressor and shut down the screw compressor
- Minimize the air dryer regeneration cycle by installing a controller based on dew point measurement
- Enclose compressors (if applicable) to prevent heat infiltration into buildings if not desired

Medium cost

- Replace older, high-maintenance air-engine driven equipment with new, high-efficiency type
- When many users demand relatively low-pressure air, consider the economics of installing a separate distribution network
- Install a pre-cooler to cool the inlet air and remove most of the moisture
- Consider installing electronic condensate drain traps (ECDT) to get rid of the water in the receiver and piping. No air is wasted when the water is ejected, as opposed to the standard practice of cracking open a receiver drain valve for continuous bleed-off. The ECDT are extremely reliable. The payback on the investment ranges from 8 – 24 months
- Install a large compressed air accumulator tank to reduce compressor cycling
- Review all operations where compressed air power is being used and develop a list of alternative ways to perform the same function
- If compressors are water cooled, look for ways to recover heat from the cooling water circuit
- In multiple-compressor installations, schedule the use of the machines to suit the demand, and sequence the machines so that one or more compressors are shut off rather than have several operating at part-load when the demand is less than full capacity
- Make piping changes necessary to shut off production areas, e.g., packaging, when there is no demand (off shifts, weekends)

Capital cost

- Install a system pressure regulator to eliminate artificial demand by stabilizing pressure at the minimum required level for production. Note: typically, 10% energy savings are achieved. (E.g., XCEED™ Demand Expander)
- Consider installing rotary drum air dryers, where the heat generated by air compressor is used to continually regenerate the air dryer desiccant, and no compressed air is consumed
- Consider installation of an airtight plastic pipe distribution network to replace old steel pipes, and eliminate corroded and leaking circuits
- For smaller or occasional compressed air uses, consider using a combustion engine-driven compressor unit, which provides a less expensive energy input and has better part-load efficiency than electrical motors, and affords heat recovery from exhaust and the engine jacket
- Check the size of the air distribution network for a “tight” fit, which causes excessive pressure losses
- Consider replacing your compressed air dryers with more efficient type, e.g., freeze dryer or rotating drum dryer
- Consider fitting a variable speed drive (VSD) to your fixed-speed compressor (typically, payback of less than 2 years may be obtained)
- Reduce idling losses and ensure the lowest possible generation pressure by constantly monitoring the end-use pressure and tying it to the compressor operation
- Review compressor loading and consider whether installing differently-sized compressors would even-out the loading by fitting the suitably-sized compressors to the momentary demand
- Recover heat from the compressors for preheating rather than paying to cool them
- On older compressors, consider installing a buffer tank to regulate compressor duty cycle

Case study:

A brewer-contributed case study: **Is my compressor sized properly to meet demand**?

Most of the literature available regarding compressed air focuses on reducing leaks and pressure in a system. These items are important however forget one of the most basic aspects of a compressed air system; has it been sized correctly to meet demand? In general an undersized system is identified quickly because it provides direct feedback to operations when one does not have enough air; however an oversized system is not as obvious but can be very costly to operate and maintain.

As a result of a capital replacement project, a detailed investigation was completed on our compressed air system. The project was initiated as a result of multiple failures throughout the year that placed our facility at risk of being unable to supply product in a timely fashion. The plan was to purchase a back-up system. Our original system consisted of one 200HP compressor that could supply approximately 800 SCFM. Detailed measurement found that at peak load, the facility only required 550 SCFM. Since we did not have a surge tank, the system was effectively blowing off and wasting 30% of the air being generated.

The end result was a system that was cycling excessively resulting in increased maintenance and hydro cost. Also, since the system was oversized, saving leaks did nothing to actually help the bottom line. Reducing consumption would have only resulted in more air being blown off and wasted. As a result of the measurements and an understanding of our demand, the system was sized with one 75HP fixed speed unit and one 75HP variable speed unit with a large surge tank. With a good understanding of our load profile, we were able size our system effectively and install a system that reduced our compressed air hydro spend by 30%.

Additional information:

An older technical manual *"Water and compressed air (M191-6/12E)",* may still be available at Natural Resources Canada (Office of Energy Efficiency) and remains a good reference.

8.8 Process gases

Carbon dioxide – CO_2 – and sometimes **nitrogen (N_2)** are process gases that have many product quality-related uses in breweries. They are used to carbonate or nitrogenate the product. They prevent oxygen from coming in contact with beer during filling and emptying of beer holding vessels and pipes and during transfers. They are used for dilution water conditioning, in bottling, canning and kegging, and eventually, during the dispensing of beer in pubs. In a modern brewery, every process stage past fermentation has a potential for use (and for release) of carbon dioxide.

Nitrogen, a cheaper gas to purchase than CO_2 and easy to generate on site, can be used for most of the applications above. Nitrogen allows for cleaning of vessels with the biocidal caustic detergents, where CO_2 use is impractical. (With CO_2, there is danger of the vessel's collapse and waste of the detergent on account of its neutralization.) For beer conditioning, nitrogen is often used in a mixture (30% to 60%) with CO_2. Its use in beer produces a much denser and stable foam head with finer bubbles, as has been practiced by an Irish brewery for decades. However, the decision to use nitrogen is preceded by production and/or marketing considerations.

Due to the lower density of nitrogen and the fact that the use of oxygen-free gas in the brewery is controlled by volume rather than by weight, the use of nitrogen can reduce the cost of such gas by between 30% and 50% of the equivalent costs for CO_2.

CO_2 is a product of yeast metabolism during fermentation of wort. Theoretical calculations show that 52% of fermentable sugars in wort will be converted into CO_2. This translates to a theoretical yield of 0.43 kg per degree Plato (^oP) attenuated. Therefore, the fermenter yield of CO_2 is about 4 kg from one hectolitre of 12 ^oP wort, or about 6 kg/hL from 18 ^oP high-gravity wort. In practical terms, the collectable quantities will be less, because of losses and absorption of CO_2 in green beer: about 0.16 to 0.24 kg/ ^oP.

The gas usage varies between 1.5 kg and 5 kg/hL of finished product, depending on product mix and the sophistication of CO_2 management. To be liquefiable, CO_2 must be at least 99.8% pure. However, since oxygen has a most deleterious effect on beer flavour and physical stability, CO_2 for beer carbonation should be essentially oxygen-free.

It should be collected in traditional systems, at 99.98% purity, or about 24 hours after the onset of fermentation, to produce gas with the lowest possible oxygen content, for example 5 ppm. For this reason, the **CO_2 is an important brewery utility with a direct, major influence on beer quality. That aspect must govern, first of all, its collection, handling and use in a brewery,** including checking for absence of flavour taints in it.

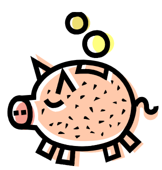
Even from CO_2 streams collected with gross air contamination (e.g., 20%) it is possible to recover pure CO_2 by means of low-temperature distillation. Collection may start as soon as the fermenter has been filled. The first gas, mostly air, will be diluted with streams from other fermenters. Low-temperature distillation plants have a better collection efficiency of 0.28 to 0.33 kg per degree of attenuation. Moreover, the method allows for simplification of pipework and valving that can influence the return on investment (ROI).

CO_2 is expensive to purchase and its on-site liquefaction and evaporation is energy-intensive; hence the potential for substantial savings in both the purchasing and processing cost areas. A brewery can and should be self-sufficient in terms of its CO_2 needs. Examples abound of well-managed breweries that sell significant surplus of CO_2 or use it for their own soft drink production. Good management of gas production and usage is the prerequisite of the goal of self-sufficiency. The first priority should be to minimize CO_2 use (reduction of wastage); the second, to maximize recovery.

The other source of CO_2 in a brewery is **boiler flue gas**. Equipment is available on the market to capture, purify and liquefy CO_2 (e.g., by the Wittemann company) from flue gas. For beer and soft drink carbonation, though, fermenter-generated CO_2 is preferred and, in some countries, legislated. Even then, CO_2 from flue gas and the non-liquefiable CO_2 from fermenters may find a wide range of uses in a brewery, among them the neutralization of brewery effluent, vessels' blanketing, etc.

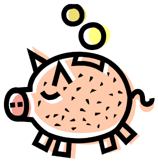
<u>Other Energy management opportunities (EMOs) and tips:</u>

Housekeeping, no or low cost



- Find out the CO_2 mass balance in the brewery. Purchase or rent gas flowmeters. For the gaseous flow, the thermal mass type with a high turn-down ratio of about 100:1 is suitable; for the liquid flow, a meter utilizing the Coriolis Effect is effective as it is independent of density, conductivity, viscosity and temperature
- Detect and eliminate all leaks
- Shut off gas when not in use, e.g., on the bottle and can fillers
- Consider blanketing fermenters with CO_2 prior to filling to reduce wastage through venting before collection and to increase yield
- Review the selection of bowl pressure in the filler. Any reduction of the bowl pressure and the reduction of the on/off control limit range (a modulating pressure control would help) will produce savings
- Review the use of gas on the canner (invariably a very large CO_2 user) and the position and state of the nozzles
- Limit the unnecessary use of CO_2 in storage tanks when the gas pressure is too high (0 to 1 bar g should be sufficient). A wasteful practice is to increase pressure during the emptying of the tank so as to maintain an adequate pump inlet pressure to prevent cavitation. Instead, rearrange the pipework to ensure a sufficient pressure at the pump under all conditions

Housekeeping, no or low cost



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- Avoid a CO_2 collection regime based on time elapsed after filling the fermenter or on drop in wort gravity. Instead, govern the CO_2 collection by measurement of oxygen content.
- Determining the CO_2 collection start when the fermenter temperature rises by 0.5°C has showed good results. That collection point was correlated to 99.5% CO_2 purity
- Review the contract with your CO_2 supplier; shop around for better prices and service

Medium cost

- Install flowmeters in a hierarchical fashion, e.g., a main meter supported by various levels of sub-metering to measure all gas usage
- Consider cross-connecting tanks to reduce CO_2consumption
- Evaluate the replacement of CO_2 with nitrogen where it makes sense
- Consider CO_2 recovery from storage and buffer tanks

Capital cost

- Install a compressor and a storage balloon for capture of flue gas for use in effluent pH adjustment/neutralization
- Eliminate wastage through the use of dead-weight valves when pressurizing tank before filling. They regulate pressure by venting excess rather than by stopping supply. Replace with appropriate control system
- Automate the collection of CO_2 gas from all fermenters through on-line gas purity measurement based on thermal conductivity (for CO_2) and/or on the use of paramagnetic or zircon electrochemical detection cells (for oxygen)
- Evaluate the cost of installing an oxygen/nitrogen generator on site (oxygen for oxygenation of wort, nitrogen for inert gas and nitrogenation use)
- Evaluate the installation of low-temperature distillation equipment

8.9 Utility and process water

Brewery operations are water-intensive. **Specific water consumption – SWC** – is a common measure, expressed as a ratio of hL of water to hL of beer.

Internationally, the Campden BRI together with the Dutch company KWA carried a number of brewery water use surveys in recent years. The latest, in 2007, included 130 breweries, all bigger than 500,000 hL. The SWC range was 2.3 hL/hL (this was the best practice) to 8.8 hL/hL, with the top 10% (decile) having the SWC at ≤ 3.5.

In the UK, the survey showed these results:

Table 8.9.1 Specific water consumption survey, the U.K.

Brewery size, hL/y	Range of SWC	Average SWC
> 500,000	3.04 – 10.41	4.0
100,000 – 500,000	3.74 – 17.28	6.56
< 100,000	3.04 – 10.41	5.91

Among the"big" international groups (information taken from corporate reports), the SWC in 2007 was for: SAB-Miller 4.6; InBev 5.0; and Anheuser-Busch (pre-merger) 5.5.

SAB-Miller had set the target to lower the SWC to 3.5 by 2015 by setting a water footprinting project for individual operations and processes; A-B had 2010 (pre-merger) target SWC of 4.0 hL/hL. In Canada, SWC reportedly averages around 5.6 hL/hL for larger brewers.

To put the information in perspective, for a brewery with the SWC of 6.5, the use of water per hectolitre of beer produced can be approximately:

Water as raw material:	1.3 hL/hL or 20%
Heat transfer;	0.7 hL/hL or 10%
Cleaning duties:	2.9 hL/hL or 45%
Other (including losses)	1.6 hL/hL or 25%

There are two aspects to water management in a brewery: conservation of use, i.e., of volume used, and of the heat the water carries.

The effort to manage water should start with preparing water balance. **Develop a mass and heat balance diagram of water use in different areas of the plant. Use the information in preparation of a water and energy conservation program.** The locations and flow rates of all water uses in the plant can be measured, and if the water meters are not available, as is common in many small breweries, use estimates. The mains water pressure, known diameter of the mains, sometimes a five-gallon bucket and a stopwatch can be used as the improvised tools to provide a reasonably accurate picture. Water temperatures should be measured. The information should be analyzed for wasteful, non-productive usage and excessive flows. A picture should emerge about what stream can be used and where, whether water reuse is possible and for what uses, and where there is a potential for heat transfer. With successful launching of water conservation initiatives, justifications may be available for installing more water flow meters elsewhere in the brewery.

Annual water costs in a brewery are substantially lower than energy costs, but water conservation is a tangible, high-visibility action to which everybody can relate and which everybody would likely support. Water saving has high PR potential. Undoubtedly, there are opportunities for conservation in any brewery. In the processes, water discharged from one operation could be piped in another, etc.

Cost of water in a brewery has two components: the cost of water purchased and the cost of sewer charges. Brewing industry was able to reduce the sewer charges by both the amount of water that went into the product as well as by the brewhouse evaporation loss. (For excessive contamination of the sewered wastewater, extra effluent surcharges may be applied.)

Leaking valves and taps, loose joints and leaking pipes can cost the brewery a lot of money over time. Chances are that in a brewery, there may be several leaks at any given time; and the losses add up. Associated costs of electricity to operate pumps, fans, water treatment costs, and maintenance increase the financial losses further.

Table 8.9.2 Amount of water and associated costs due to leakage:

Leakage rate	Monthly loss (m^3)	Monthly cost $ *)	Yearly loss (m^3)	Yearly cost $ *)
One drop a second	0.13	1	1.6	10
Two drops per second	0.4	2	4.9	20
Drops merging into a stream	2.6	10	31.8	127
1.6 mm diameter stream	9.4	38	113.5	454
3.2 mm diameter stream	29.5	118	354	1416
4.8mm diameter stream	48.3	193	580	2320
6.4 (1/4") mm dia. stream	105	420	1260	5040

Note: *) approximate cost at $2/m^3 purchased water and $2/m^3 sewered water; the figures are rounded off. Use your actual costs to calculate the potential financial loss in your circumstances.

A brewery may have several systems and uses for water, such as process cooling water, potable water, domestic hot water, boiler feedwater, tunnel pasteurizer water recirculation, soaker (bottle washer), keg washer, can rinsers, cleaning-in-place (CIP) and rinsing of process equipment; mashing and sparging; high-gravity beer dilution (particularly for light beers), line and filler flushing, floor washing, etc. They have in common the similar inefficiencies and, because of the water heat content, also energy management opportunities. (E.g., the incoming water temperature may be only 12^{o}C, yet the temperature of the total brewery effluent may be 28^{o}C.) The water should be re-circulated as many times as possible through these operations to prevent wastage.

Open systems, such as evaporative coolers, i.e., cooling towers are commonly used. They need additional energy to drive the fans that move the air through as well as water make-up to compensate for evaporation, drifts and the necessary blowdowns. The water has to be treated to prevent scale and slime formation and corrosion. Cooling towers cool down the returning water to a level, which is usually about 6^{o}C (10^{o}F) above the ambient wet-bulb temperature.

Closed-loop mechanical water chillers are using the refrigerant condensing coil to extract the heat. They do conserve water, produce very cold water and eliminate the need for water conditioning chemicals, but are more expensive to install and run.

The cooling of air compressors requires close control of the cooling water temperature, too. Both undercooling and overcooling can cause serious mechanical damage to an air compressor and it is best to consult with the air compressor manufacturer.

In all projects involving the heat content of water, proper insulation of tanks and pipes is necessary. (See the respective coverage here.) Pipes carrying hot or chilled water (or wort or beer, of course) should be well insulated to prevent heat loss or gain. Chilled-water piping should also have a vapour barrier to prevent condensation form saturating the open-fibre insulation.

The hot water energy potential can provide useful service in other than technological operations (mashing, sparging, washing, pasteurizing, etc.), such as in space heating, steam generation, to temper make up air, as well as, through the use of heat pumps, for air conditioning.

Benchmarking tools, e.g., WaterSaver®, are available from www.bri-advantage.com.

Case study: Minimization of water usage used for cooling air compressor

A 60 HP air compressor was being cooled by an unrestricted flow of water through the compressor cooling coils. The water was heated from 18^{o}C to 29^{o}C, and the compressor oil was at 32^{o}C; it was supposed to operate at 66^{o}C. The two options for reducing water consumption were: install a gate valve and/or recirculate water through a small cooling tower.

In the case of the gate valve, a small hole calibrated to guarantee the necessary minimum flow rate acceptable to the compressor manufacturer was drilled through the gate. This guaranteed that the water would not be accidentally shut off, yet there was a provision to adjust the future flow rate as necessary and to flush the line from time to time to remove sediment.

The cooling tower would permit rejection of heat gained by the cooling water and its recirculation.

The flow rate of cooling water could be reduced to the point where the water would exit at 63 ^{o}C, allowing the oil to remain at 66^{o}C.

The new flow rate is determined by the formula:

$$NF = \{(29^{o}C – 18^{o}C) : (63^{o}C – 18^{o}C)\} \times OF\text{; where:}$$

OF = old flow rate, L/h

NF = new flow rate, L/h

Savings are calculated using the formula:

$$CS = L \times HR \times CF\text{; where:}$$

CS = cost savings, \$/y

L = OF – NF, expressed in m^3

HR = yearly operating time of the compressor in hours, h/y

CF = cost of water consumption, \$/ m^3

The simple payback for just the gate valve installation was 1.4 days; for the more complex cooling tower installation (costing \$7,600), it was 1.2 years.

Case study: Optimizing a hot water system in the brewhouse

In a European brewery with annual production of one million hectolitres, the wort was cooled with water in a heat exchanger, then heated to 60 ^{o}C and used as brewing water. The surplus hot water was drained. A new \$120,000 wort cooler with a larger heat transfer area was installed and produced 85 ^{o}C water from the wort cooling. A larger water buffer tank was also installed. The 85 ^{o}C water was used for mashing, for make-up water in the bottle washer and as hot water supply for CIP plants in the brewery.

Reduced water consumption of 40,000 m^3 and reduced fuel oil consumption of 340 t/y generated a simple payback period of approximately 3 years.

Case study: Installing cooling tower for a tunnel pasteurizer

A 500,000 hectolitre per year brewery, which used an open-loop cooling system for the tunnel pasteurizer, installed a cooling tower to change to a closed-loop system. The use of the cooling tower, which required an investment of $45,000, resulted in savings of 50,000 m^3/y and a simple payback period of 1 year.

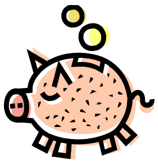
Other Energy and water management practices and tips (EMOs):

Housekeeping, no or low cost

NOTE: many of the items below should be part of the preventive maintenance (PM) or predictive maintenance schedules.

- Examine product scheduling and vessel & equipment cleaning practices, where economies in water consumption (e.g., in water reuse or in CIP) can be obtained easily
- Examine water use patterns and reduce water consumption to the minimum necessary
- Maintain the system; stop leaks promptly
- Reduce pump-operating time where possible.
- Do pump seals leak? – replace leaking seals ASAP
- Are any pumps fitted with packing-gland seals? Consider replacing these pumps with new units with mechanical seals
- To prevent water losses, inspects pipes frequently and repair leaks promptly
- Instill good housekeeping practices in all employees, e.g., do not let run water hoses or taps uncontrolled (especially in the cooled areas, where the water adds to the refrigeration loads
- Do not let the eyewash fountains run as a drinking water source; provide drinking fountains instead
- Ensure that water supply for processes stops during idle periods (e.g., after-filler bottle crown flush, can rinser, last rinses in the bottle washer, etc.
- Remove stagnant, redundant branches of the water distribution network
- Monitor and control the cooling-water temperature so that the minimum quantity of water required to perform the cooling is used

Housekeeping, no or low cost



(Continued)

- Water pumps should be shut off when the systems they are serving are not operating. This measure will reduce the electricity costs for pumping, and in case of cooling water, the cost of water treatment
- Optimize pump impellers (change out) to ensure that duty point is within the optimum zone on the pump curve
- Maintain pumps through regular inspection and maintenance to monitor for early indications of failure
- Strainers and filters should be checked regularly to ensure that they do not become clogged; clogged filters cause losses in pipeline pressure
- Reduce evaporation from tanks by installing (or closing) covers
- Check and adjust as necessary the appropriate water heating set points, aiming at the minimum required temperature levels. Consider switching off the heating regime for weekends and holidays
- Prevent or minimize water overflow occurrences (especially hot water)
- Maintain proper control over water treatment to ensure that design flows are maintained
- Maintain properly monitoring and controlling equipment.
- Ensure calibration or verification of the temperature and pressure sensors
- Identify all hoses and ensure that the smallest diameter necessary is used for the task
- Review the bottle washer operation
- Ensure that tunnel pasteurizer operates in a thermally balanced mode
- Ensure correct function of spray nozzles in the tunnel pasteurizer

Medium cost

- Reuse and/or recirculate cooling waters and process waters imaginatively (e.g., use a pump seal water to serve as an air-conditioning unit
- Use process or cooling water as a heat-exchange medium in your ventilation or heating system.
- Consider placing a water/air heat exchanger system inside the brewery, to help with the heating load in the winter; etc.)

Medium cost

(Continued)

- Collect uncontaminated “wasted” water if the rate of its generation exceeds the rate of the immediate reuse, rather than emptying it down the drain. Install an inexpensive FRP off-the-shelf tank or a second-hand vessel for the collection and use of the water later. Size these holding tanks properly. Use these collection vessels to even out the supply/demand ratio in your water *multiple* reuse projects
- Remove existing design flaws, such as bottlenecks, sharp elbows, wrong-sized valves that restrict flow
- If pump flows vary consistently, consider using variable speed drives or two speed motors
- Collect uncontaminated cooling water for reuse
- Reuse all rinse water form cleaning operations (with due regard to product quality implications, wherever possible, for example the cleaning-in-place (CIP) last rinse
- Reduce water heat loss or gain by proper insulation of pipes and vessels
- Install water system expansion tanks on closed loop systems, to serve two purposes: when the water is hot, wastage through relief valves will be prevented. When the water is cold, the contracted volume would normally demand make-up water to keep the system filled
- Reduce friction losses and the associated pressure drops by streamlining and correct-sizing of water pipes
- Reduce water leakage / wastage by bringing the water pressure down in areas where high pressure is not needed
- Review correct size and choice of water pumps
- Install water flow regulators for sanitary uses; delayed closing or timed flow taps on wash hand basins and reduced-flow shower heads
- Install water meters in different process areas to monitor consumption on an ongoing basis. Use the data to identify zones, equipment and crews with either inconsistent or inefficient performance to correct deficiencies and o set progressively tighter consumption targets
- Install the European-type on-demand gas water heaters for sanitary use (as a brewery did)
- Review the areas where high-volume, low-pressure rinsing or flushing makes sense (e.g., at the bottle filler) and where the use of low-volume, high-pressure (nozzles) water flow is called for
- Fit hoses with automatic cut-off valves where appropriate (guns)

Medium cost

(Continued)

- Install delayed closing/timed flow taps on wash basins in the restrooms
- Consider replacing old hot water boilers with high-efficiency units (about 95% with condensing heat recovery)

Capital cost

- Implement a plant-wide water system with multiple reuses of process water, on heat cascading principle
- Can a once-through system be converted to a circulating system? Revise the water distribution system to incorporate multiple reuse (recirculation) of process water wherever possible, employing suitable heat recovery regimes, and implement the measures
- Install closed-loop cooling water systems (cooling towers) to eliminate once-through cooling water (double costs on water and sewerage)
- Review pump sizing, water pressure requirements and delivery distances versus the piping diameter; often, smaller pumps but larger diameter piping to reduce friction losses provide for a better energy efficiency and make a better economic sense when all costs are considered
- Upgrade pumps
- Streamline piping systems. Often, brewery grew by adding new area or processes without much thought given to piping systems: remove redundant, unused branches.
- Make the water management a part of computer-monitored and controlled system of overall brewery utilities management (M&T technology, described elsewhere in this *"Guide"*)
- Consider employing heat pumps for the combined application of heat extraction and provision of chilling to process water and other fluids
- Consider using waste heat to drive wastewater evaporator, for sludge disposal (if you have a wastewater treatment plant – WWTP – on site.)

8.10 Shrinkage and product waste

Have you dollar-quantified ***all*** components of poor quality in your brewery ?!?
(Some examples on the following page.)

Poor quality, which is represented also by reworked, rejected and scrapped product represent a massive waste of labour, materials and energy that is rarely quantified in a typical brewery. More often than not, it is accepted as part of the production cycle, yet the dollar losses may be enormous.

It takes an effort to improve things. A well-implemented management system such as one using the ISO 9001:2008 international standard principles dealing with quality management systems, the HACCP norm, and the ISO 14001:2004 environmental management standard, will minimize occurrences of product-in-process being reworked or rejected and finished product being scrapped. Omitting the serious negative product quality implications, some examples of energy waste involved in these employee-demoralizing occurrences (symptom and commonly applied solution) are:

Table 8.10.1 Energy waste involved in process problems:

Process problem	Commonly applied solutions
Contaminated pitching yeast	Dump
Primary or secondary beer outside of specifications	Blend off; in serious cases (e.g., phenolic taint, massive microbial contamination) dump
High gravity beer dilution water (oxygen content higher than specifications or CO_2 content outside of specifications)	Dump or reprocess
Beer in packaging cellar tanks (oxygen content higher than specification)	Purge with CO_2 or blend (return to secondary storage)
Beer in packaging cellar tanks (CO_2 content outside of specifications)	Carbonate in place, blend or reprocess
Packaged beer outside of specifications or primary container fault; underpasteurized; seriously overpasteurized; glass fragments in bottles; "butterfly" glass; flavour taint from undercured cans; seriously stained cans; use of wrong labels, crowns, cans; poor secondary packaging)	Dump
Returns from the trade, recalls	Reinspect, repackage or dump

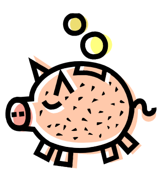
The above examples involve some of the following losses, often several together:

- unrealized profit, i.e., profit losses
- decreased productivity
- increased direct labour expenses and indirect expenses; may include overtime
- wasted energy in pumping, heating and cooling of large volumes of water and beer (i.e., wasted fuel, steam, electricity)
- *de-facto* reduction in plant production capacity
- wasted CO_2
- increase in volume and organic loading of brewery effluent
- increased effluent surcharges or increased expense in wastewater treatment,
- wasted raw materials
- wasted packaging materials
- possible impairment of product quality and market position
- demoralizing influence of poor production quality on employees

The impact of an individual event may not seem much but cumulatively, over a period of time, losses can be quite large. Breweries should analyze and quantify some recent occurrences of losses listed above in order to assess the negative impact they have on the brewery on an annual basis.

Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Document process procedures and work instructions, with designations of responsibility and accountability
- Monitor routinely and quantify losses cumulatively over a period of time, to report them and to prevent or limit their occurrences
- Educate all employees about the cost and other negative implications of poor quality production. Solicit their input and ensure their participation in the remedial and preventive actions

Medium cost

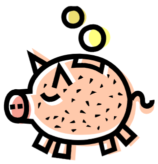
- Implement management systems (along ISO 9001, HACCP and/or ISO 14001 standards, alone or in combination to ensure quality production and due care of environmental issues

8.11 Brewery by-products

The vast majority of Canadian breweries sell their by-products, chiefly spent yeast and spent grains, in wet state. Rarely do they improve their market value by drying them even though drying substantially boosts the profit potential.

Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Collect spent yeast and spent grains with minimum moisture content
- Review the existing contract with spent-yeast and spent grains haulers
- Investigate more profitable ways of by-product disposal
- Investigate composting or tillage (e.g., diatomaceous earth, wastewater treatment plant sludge, undistillable waste beer)

Medium cost

- Collect and add trubs to the spent grains
- Collect waste beer for off-site disposal or sale

Capital cost

- Install/upgrade drying equipment to take advantage of modern, energy-saving technologies, of which many are suitable for spent yeast processing and spent grains drying (spray drying and ring-drying for spent yeast, fluidized-bed and tube-shell steam drying for spent grains, etc.)
- Distill alcohol from waste beer and sell it; evaporate the stillage in multiple effect vacuum evaporators and add to the spent grains

8.12 Wastewater

Wastewater presents a problem for any brewery: there is a lot of it; it is loaded with organic and inorganic matter making it expensive to treat on-site, or pay for treatment elsewhere. The best performers have a ratio of wastewater discharged to beer produced of 1.5 : 3.5. The ratio reflects water contained in the product, evaporation losses in the kettle and evaporative condensers and water contained in spent grains, trubs and spent yeast.

Brewery wastewater has high organic matter content; it is not toxic, does not usually contain appreciable quantities of heavy metals (possible sources: label inks, labels, herbicides) and is easily biodegradable. Brewery wastewater is characterized by these main parameters:

- Volume (m^3)
- pH
- SS – suspended solids , mg/L
- BOD_5 – biochemical oxygen demand, determined after a 5-day incubation period, mg/L
- COD – chemical oxygen demand, mg/L
- and a host of lesser parameters, such as total nitrogen, phosphorus, fats and greases.

Municipal treatment plants welcome it. Municipal treasurers welcome it, too, as it often offers a chance to collect significant effluent surcharges because of high BOD_5 loading for the treatment plant. (Typical range is 1,000 to 2,500 mg/L BOD_5.) In any municipality, the maximum permissible contaminants of wastewater are set by relevant by-laws. Wastewater may include the following charges - depending on the location:

- sewerage – the cost of conveying the liquid; volume-related
- treatment charge; volume-related
- BOD_5 charge – typically if in excess of 300 mg/L of BOD_5
- suspended solids (SS) charge – typically if in excess of 350 mg/L of SS
- pH charge – typically if outside of range of pH 6.5 – 10.5. (However, many municipalities increasingly prohibit pH outside the range)
- sludge treatment charge.

Often, the two pollution indicators, BOD_5 and SS, are combined in an effluent surcharge formula, and others are combined or hidden in areas such as water supply costs.

Municipalities, faced with rising costs for sewer system upkeep are showing little tolerance for pH transgressions exhibit wear and tear on the sewer pipes and are forcing industries to comply with their bylaws. Canadian breweries are therefore often installing pH-adjustment systems on their brewery processes effluent.

pH can be adjusted with the aid of an acid (sulfuric is the cheapest acid available) or CO_2 (bought, or brewery fermenter - or flue gas-generated). Several systems are commercially available. Of the two pH change agents, CO_2 is the cheapest and safest and cannot over-acidify the brewery effluent.

Storm sewers, with much tighter pollution criteria, can be contaminated by spilled oil or

Fuel form cars in the parking lots, spilled spent yeast or spent grains during loading for transport and spilled beer from road tankers. Contaminated storm sewer water can pose serious, costly difficulties with a number of authorities. Hence - procedures must be implemented to prevent storm sewer water contamination.

Most Canadian breweries do not have their own wastewater treatment plants (WWTP). They have to pay either private contractors or municipalities for the treatment of their wastewaters. It is very costly. However, it is also very costly for those few breweries in Canada with their own WWTP to process the brewery effluent: the operating costs of staffing the plant, electricity consumption, treatment chemicals, monitoring and sludge disposal are huge.

Therefore, **every brewery should first attempt to eliminate the wastewater pollution at source**. Every measure should be taken to prevent trubs, spent yeast, spilled beer, spent grains, diatomaceous earth (D.E. or “filter aid”), etc. from reaching the sewer pipe. These actions will literally prevent pouring money down the drain due to effluent surcharges and product and by-product losses.

The following **BOD_5 values**, in rough figures, can be found in the main categories of contaminants in the brewery:

- Dense liquid spent yeast: 160,000 mg/L BOD_5
- High gravity beer: > 120,000 mg/L BOD_5
- Beer (depending on alcohol %) 50,000 to 100,000 mg/L BOD_5
- Trubs: 45,000 mg/L BOD_5

A brewery can save large sums of money by improving the quality of the effluent it produces in several ways by reducing:

- “Strength” of its effluent (and its volume)
- Energy consumption associated with pumping, blending and pH-adjusting
- internal wastage of product-in-process and saleable by-products
- Cost of using pH-adjusting materials.

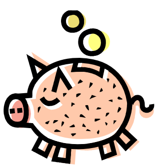
For a brewery, savings can range from small sums of dollars to million-dollar sums. It is worth the effort to examine each brewery's situation.

Any beer that is not collected ends up in the effluent. Beer is lost through process tank emptying, water push-throughs in the filter and in beer lines at the fillers, packaging area rejects (low fills, foam picks, poor labeling, quality defects), exploding bottles in the pasteurizer, beer frozen in transportation, and returned beer from the trade. This all costs a brewery dearly in many ways.

> The first task to consider: **minimize in-brewery beer losses**, typically 2% to 5% of total beer production and even more, by improvements in product-in-process management.

Other Energy and water management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Remove hot wort trubs with the minimum amount of high-pressure water, and
- Dispose of hot wort trubs by mixing them with spent grains
- Prevent leakage of spent grains liquor from the spent grains holding tanks
- Investigate opportunities for profitable or less expensive disposal of spent yeast and waste beer
- If operating a WWTP:
  - review the efficiency of oxygen transfer to the mixed liquor;
  - upgrade the equipment, adjust the aeration rate to suit the load and the ambient temperature;
  - consider the power demand implications;
  - avoid using high-pressure compressed air for aeration;
  - if using sub-surface air dispersion, review the state of membranes (discs, nozzles); and
  - review the efficiency of electric motors and drives as appropriate.
- Investigate off-site disposal of waste beer (e.g., to a distillery, feed-lot operations, etc.)

Medium cost

- Modify process equipment and/or process procedures to prevent effluent contamination, e.g.:
- collect all waste beer for off-site disposal,
- re-use last runnings (spargings) as mash-in or lauter tun foundation water (saving heat, water and some extract as well),
- collect spent yeast and spent diatomaceous earth, etc.
- Inactivate the collected spent yeast by steam and mix it with spent grains for disposal (rather than sewer it)
- Use biogas from an anaerobic plant (if installed at a brewery) to augment the brewery's energy needs
- Negotiate with appropriate authorities the ability to discharge some non-contaminated
- effluent streams, such as pasteurizer and compressor cooling waters into storm water sewers (assuming that no further recycling opportunities exist for these streams)

Capital cost

- Install/convert the pH-adjusting station to use CO_2 or flue gas
- Investigate conversion of the current wastewater aeration equipment for a more efficient system (e.g., replace surface aeration with sub-surface aeration by the hyperparaboloid-shaped mixer/disperser

8.13 Building envelope

Older breweries, erected before 1980 when the energy was relatively cheap, are often inadequately insulated and sealed. Minimum requirements for energy conservation in (new) buildings are spelled out in several norms, e.g., Model National Energy Code for Buildings, 1997, updated for 2011; Ontario Building Code 2006 (amended 2009). Retrofits have to comply with them also.

To upgrade wall insulation inside of the buildings is often nearly impossible, for many reasons. In such cases, it is often possible to add insulation to external side of the buildings and cover it with new weatherproof cladding.

Table 8.13.1 Minimum thermal resistance of insulation

(based on degree-day zones – see your local building permit office for guidance)

Building element exposed to the exterior or unheated space	RSI (R) value required		
	Zone 1 <5000 degree-days	Zone 2 >5000 degree-days	Electric space heating Zone 1 & 2
Ceiling below attic or roof space	5.40 (R31)	6.70 (R38)	7.00 (R40)
Roof assembly without attic or roof space	3.52 (R20)	3.52 (R20)	3.87 (R22)
Wall other than foundation wall	3.00 (R17)	3.87 (R22)	4.70 (R27)
Foundation wall enclosing heated space	1.41 (R8)	2.11 (R12	3.25 (R19)
Floor other than slab-on-ground	4.40 (R25)	4.40 (R25)	4.40 (R25)
Slab-on-ground containing pipes or heating ducts	1.76 (R10)	1.76 (R10)	1.76 (R10)
Slab-on-ground not containing pipes or heating ducts	1.41 (R8)	1.41 (R8)	1.41 (R8)

Reference: Ontario Building Code 1997; for illustration only

Buildings with large south or southwest facing walls can be retrofitted with a type of a solar wall (e.g., by now internationally well established Canadian-developed SolarWall™) for even greater energy efficiency in space heating.

- *Double glazing is the minimum standard for Ontario*
- *Chose improved sealed units for north-facing and highly exposed widows*
- *Low E-coatings work best together with gas fill*

Windows can present both a challenge and opportunity for energy conservation. May older brewery buildings have single-glazed, inadequately sealed windows. They are often dirty, not cleaned, forgotten by maintenance or cleaning crews (se the influence on lighting). Replacing them with double or triple-gazed units is expensive. Instead, fitting them with panels of plastic or glass-fibre may be used to advantage. Also, the glass, exposed to sun, may be fitted with a sun-deflecting film, to reduce heat gain (in the summer).

Table 8.13.2 RSI / R insulation values for windows:

Glazing layers	Glazing type	RSI / R value
Double – one air space of 12 mm	Conventional, air	RSI 0.35 / R2
	Low-W	RSI 0.52 / R2.9
	Low-E with argon gas fill	RSI 0.62 / R3.5
Triple – two air spaces of 12 mm	Conventional, air	RSI 0.54 / R3
	Low-W	RSI 0.69 / R3.9
	Low-E with argon gas fill	RSI 0.76 / R4.3

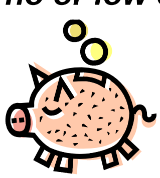
Some facts about glazing:

- Standard triple glazing adds an extra air space (also weight) and thus insulation
- Glass coatings reduce heat emissivity and reflection Low emissivity (low-E) coating reduces radiant heat through the glass and achieves about the same insulation as uncoated triple glazing
- Gas fill – filling the inner space with argon or krypton increases the insulation still further
- Triple glazing with both Low-E and gas fill gives the insulating value almost five times as great as that of a single pane window.

Consider also the state of your brewery doors. They lose the most heat when they are open. Installation of automatic door closers, vestibules, or revolving doors reduces those losses. Inspect the loading dock seals for proper fit and damage. Review whether the exterior doors and doors to chilled areas are insulated, and weather-stripped.

Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Repair broken windows, skylights and doors
- Check the thickness of isolation in walls and roofs
- Examine all openings for cracks allowing air to leak in and out the building
- Caulk or weather-strip the cracks
- Inspect the loading dock seals for proper fit and damage

Medium cost

- Seal the building first, to reduce air leaks – both infiltration and exfiltration – through openings such as doors and windows
- Consider shading or curtaining windows on the inside, or shuttering them on the outside, to keep the summer heat and winter chill out (watch for building codes and ASHRAE regulations)

Medium cost

(Continued)

- Plant shrubs and trees around the buildings
- Install sun shades (sun trellis) over the windows to reduce summer heat gain
- Review the possibility of installing automatic door closers, vestibules, or revolving doors
- Locate the heat exchanger for the flue gases cooling inside the brewery building: it will help heat it in the winter. An additional benefit: worries about freeze-up or charging the system with antifreeze are minimized
- Install an automated damper system on the air compressors to keep the heat in the building during the winter
- Install air curtains at loading bays
- Consider linking exhaust fans in washrooms, kitchen, etc., to the light or equipment switch
- Consider reversing the roof exhaust fans in areas where it is possible (e.g., relative absence of dust), in the wintertime, to mix with and temper the outside air to provide heat to areas below
- Consider installing double-door vestibules or wind breaks in north-west locations of the openings

Capital cost

- Add measuring ad monitoring, and control devices
- Incorporate the building features into the total plat energy management system
- Evaluate the economics of replacing present insulation type with another type. Consult with unbiased professionals.
- Consider innovative use of passive or active solar heating technology for space and/or water heating, especially when combined with improved insulation, window design and heat recovery from vented air
- Installation of a solar wall (e.g., SolarWall™, Trombe) on the building's south or south-west sides to provide effective heating
- Consider using evaporative cooling of flat roofs to reduce air-conditioning loads in summer
- Review the adequacy of the building envelope's thermal insulation, particularly roofs, and correct if required
- Consider installation of new insulated roof membrane with covering of heat-reflecting silver-coloured polymeric paint to lower the heat transmission

Capital cost
(Continued)

- Consider using heat generated by equipment (e.g., compressors, pasteurizers, wort coolers, economizers, etc.) for building heating in the cold weather
- Consider upgrading windows
- Consider upgrading doors and bay doors

Case study:

A brewer-contributed case study: **Take advantage of your climate - cellars:**

Historically our cellar exhaust fans turn on based on CO_2 levels in the cellars; they turn off when levels drop down to acceptable levels. Our fresh air make-up comes from outside in the summer, however in the winter a damper was closed and make-up air came from inside so that -20 ^{o}C air was not freezing lines. This year an extra damper was installed and with minimal automation, we are able to temper make-up air and use outside air when cold all winter long. Supply air to the cellars is consistently delivered at ^{o}C and the bulk of the air comes from outside. We expect this to have a fairly large impact on refrigeration loads in these areas and plan on applying this to other areas. Naturally, the first approach should be to minimize CO_2 leaks in the cellars in the first place but sometimes we can lag in this area and processes are difficult to change with existing infrastructure.

8.14 Heating, ventilating and air conditioning (HVAC)

Heating, ventilating and air conditioning (HVAC) equipment are not normally major electricity users in a brewery, but they present many opportunities for savings. Many of these opportunities involve good housekeeping and therefore require an employee education campaign.

The paradox situation, when, in winter, the brewery building's heating is operating at maximum, while the loading door is left wide open, is not uncommon. The heat lost from a building in winter must be overcome by the building's heating systems, which adds to the brewery's operating costs. Typically, a brewery has a lot of waste heat available, which could be used for space heating. The challenge is how to use it intelligently to create a comfortable working environment.

It helps to start by creating a heat balance – describing the heat sources and heat sinks in the brewery, in a quantified way. The ventilation system needs to be included in the equation. Since neither can be effectively solved in isolation, aim at a synergistic solution. Use some of the ideas listed below, as well as those described elsewhere in the guidebook.

Commonly, breweries have problems with the ventilation of work zones. Usually, there is an imbalance between fresh air and exhaust air. The problem is often compounded by locally-dusty or moisture-saturated atmosphere and sometimes high carbon monoxide (CO) content. For this reason, the construction of breweries traditionally allowed for ample sizing of roof monitors and exhaust stacks. That was often done with little thought as to the proper location of these vents, and to distribution of air make-up.

Excessive air exhaust results in high under-pressure in the building and draught problems. In production areas inside breweries, the existence of too many exhausts points and the lack of a system for air supply may have created this negative pressure. At the same time that the production creates a heat surplus (wasted by the exhausts), additional heat must be supplied by other means to the fresh make-up air being brought in from the outside in the wintertime. To add to the waste, city water may be sewered after providing just once-through cooling.

Here are a few examples of how others have dealt with the problem:

Unnecessary exhaust of 10,000 cfm translates to about $3000/y in heating costs!

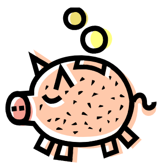
A brewery dealt with its ventilation needs in a combined way: flue gases were passed through scrubber/heat exchanger, and the incoming air was preheated in winter. The incoming ventilation air system adjusted to the changing needs by regulating the fan's capacity in the inlet section. This was regulated by monitoring the air pressure in the incoming air channel. The air exhaust system had suction points located in the most-needed areas of the plant, with separate fans for each of the zones. The exhaust fans also had speed regulators. The whole system, connected to a central monitoring system and controlled by a PC, obtained a balance between the inlet and outlet sections of the total ventilation system. The energy costs for the plant ventilation were halved as the result and the incoming air was of higher quality than before.

Do not undermine the function of a well-designed ventilation system by leaving doors and windows open unnecessarily – otherwise it will never work!

Another plant opted for a simpler approach, but still divided the plant into separate ventilation zones. Only the sections where operations were taking place were fully ventilated; others where no work was going on, had ventilation valves only partly open to allow minor ventilation.

Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost

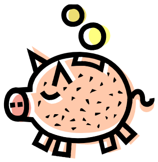


- Conduct a survey of HVAC in the brewery. Check the temperature of the workplace for adequacy and adjust as necessary
- Review the condition of HVAC equipment (the function of louvers, control valves, temperature controller) and correct as necessary
- Ensure the HVAC equipment is serviced regularly either by outside contractors or by the brewery maintenance staff

Patiently, consistently and persistently try to implement a culture change: i.e., changes to employee behaviour towards energy management can lead to a virtually cost-less achievement of substantial savings. Some of the items are listed below:

- Close windows, doors and receiving/shipping bay doors in cold weather
- Report high ambient temperatures rather than opening windows (so qualified adjustments can be made)
- Assign someone (e.g., maintenance) to switch-off machinery at the end of the work week
- Remove superfluous lights
- Prevent blockage of radiator and ventilation grids
- Ensure correct setting of controls on make-up air units; lower the temperature setting if possible
- Do not leave doors open (e.g. from the corridor into the cellars, external doors – doing so negates the HVAC settings in the brewery and the correct function of the HVAC equipment
- Install locks to thermostats and HVAC controls to prevent tampering and misuse by unauthorized employees
- Eliminate heating or cooling of all unused rooms
- Lower the thermostats for the weekends (say, to 15^{o}C)
- Raise the thermostats a bit in summer and lower them a step in

Housekeeping, no or low cost



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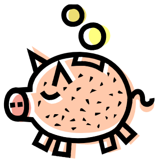
the winter, when possible (18^{o}C should be a comfortable brewery building temperature)

- Lower the heating temperature in storage areas to as low as possible
- Use "free cooling" with low-temperature winter air
- Install setback timers on thermostats controlling space heating during non-working hours
- Use de-stratification ceiling fans in areas with high ceilings, such as bottling halls. (Note: the usual 5' or 6' diameter "Casablanca" fans have lower energy requirements than central ceiling-level heating / ventilation air handling units. Also: in a pharmaceutical plant in Alliston, Ontario, very large diameter ceiling fans (12' to 16') were employed for gentler air circulation, with further energy savings)
- Check the adequacy of ventilation. Use the minimum acceptable ventilation Find out whether the plant is under negative pressure because too much air is being drawn out or positive pressure from too much supply air being blown in
- Minimize building exhausts. Close off roof vent stacks in cooler weather/seasons to minimize heat loss. Make sure the dampers work
- Shut down exhaust or supply fans during non-working hours
- Clean/exchange intake air filters regularly
- Ensure that heating and air-conditioning systems operate only when required
- When no production is going on, and on weekends, and especially during colder weather and in winter, reduce the amount of fresh air brought into the plant as much as possible
- Turn-off air-conditioning units in the cafeteria and in the offices on weekends
- After the hot air from compressors has been generated, re-circulate it back into the building for heating purposes (in winter)
- Keep the doors/loading bays closed to allow the ventilation system to work properly
- Switch off ventilation and/or heating when not required
- Shut down dust collection, ventilation and makeup air when not required
- Assign someone to turn-off the fans, close the vents, etc. at the end of the week. Prepare a checklist so nothing is overlooked
- Conversely, put someone in charge to switch it on at the beginning of the workweek

Housekeeping, no or low cost



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- Incapacitate some non-essential exhaust fans during the winter months (take the fuses out)
- Eliminate leaks and pressure loss points in supply and return air systems
- Examine your present system – perhaps the original dust collection / exhaust system was designed to handle larger volumes of air than necessary for ordinary plant operations. Maybe some of the fans could be taken off-line, at zero cost, for immediate benefits of:
    - Reduced maintenance
    - Lower energy costs
    - Reduced emissions
    - Reduced noise

  You can simply verify this by turning the selected fans off and watching what happens
- Pay attention to the upkeep of your baghouse/dust collection system; monitor both its integrity and resistance (i.e., proper functioning) by a differential pressure gauge (e.g., water column gauge)
- Monitor CO (carbon monoxide) levels regularly (either by manual checking at head level or by installing an automatic sensor-driven alarm in cellar areas. It will give an additional indication of the ventilation effectiveness
- Keep the motors on fork lift trucks and other brewery vehicles well tuned, to reduce the excessive release of CO into the brewery atmosphere, which increases ventilation demand
- Do not let the motors on fork lift trucks idle; switch them off when not in motion
- Watch for “short-cutting” of heated make-up air directly to a nearby exhaust fan
- Delay the start of brewery ventilation at the start of operation until the heat of bottle-washing, pasteurizing, etc., has warmed up the air inside
- Where required, cut small openings into large doors to allow the passage of forklift trucks; use transparent curtains to prevent continuous blasts of cold air from outside

Medium cost

- Install infrared heating for large open areas (replace steam or hot water heating radiators) to heat people rather than space; in addition, radiant heaters do not require air-handling mechanisms, saving further energy

Medium cost

(Continued)

- Minimize unwanted infiltration of outside air into the brewery also by other means (reseal cracks, repair or replace doors, link loading bay doors opening to the activity, etc.)
- Use economical radiant heating directed at workstations rather than general space heating
- Install strategically located exhaust hoods over dusty/hot areas. Make sure that they are amply dimensioned, so the heat or dust does not escape into the general space
- Recapture the heat that accumulates high up in the brewery spaces – push it down in the wintertime (filter it if required) and control it thermostatically should the outside temperatures be extremely low
- Fit the exhaust fans with variable speed drives to match the ventilation rate to the need
- Investigate whether you can supply outside air directly to a particular operation to conserve the heated plant make-up air
- Install high-velocity air-curtains at loading bays and other large openings

Capital cost

- Use reflective insulation, or paint flat roofs white over refrigerated areas
- Install thermostatic air vents
- Evaluate the application of recently developed regenerative rooftop heat recovery ventilation systems
- Replace the general ventilation of the entire area with locally situated, hooded exhausts from areas which need to be ventilated
- Consider the provision of fresh air of constant temperature in the brewery by the installation of a new ventilation system using a rotary heat exchanger. The warm exhaust air heats the incoming air in the exchanger. The temperature is controlled by the number of revolutions of the exchanger
- Consider utilizing heat pumps (or ground heat pumps) for combined heating and cooling of the brewery facilities

8.15 Lighting

Improving the energy efficiency of lighting is one of the “high visibility, good PR optics” projects in any industry: everyone can relate to it, and see the results.

Bulb efficiency %:
Incandescent = 100
Fluorescent = 300
Metal halides = 400 -600
HP sodium = 450 – 700
LED = higher by several orders of magnitude

The evaluation of lighting systems is mandated by the 2009 *Energy Efficiency Act and Regulations* that set minimum requirements for lamp efficacy and lighting quality. The energy audit of your brewery should help in determining the conformance to the regulations. Electric utilities, manufacturers of lighting products and consultants can also provide help.

Our drive to increase lighting energy efficiency should not diminish the requirements of adequate lighting of the workplaces. The ranges of existing lighting levels in Canadian breweries should comply with the requirements by the Illuminating Engineers Society *www.iesna.org/*. Often not realized is the fact that demands on lighting levels' intensity do increase as workers age.

It is worthwhile to consider this fact for several reasons. Adequate lighting levels that correspond to the age of the workers have many tangible and intangible benefits that are often overlooked:

- Improve morale and reduce absenteeism
- Positively influence quality (i.e., resulting in improved customer satisfaction)
- Allows for better control of costs by reducing defects and rejects (particularly in packaging, at pasteurizer bottle inspections, packaging, labeling, etc.)
- Provides inducement to experienced older workers to stay on rather than retire early
- Improves housekeeping and safety records (i.e., cleaner, more orderly workplace and lower accident and insurance costs)
- Positively influences the company's image and the personnel's self-image

Where applicable, try to take advantage of natural daylight (skylights, windows). Think about ways to facilitate the window/skylight cleaning, though.

In reducing lighting costs, focus therefore on improvements to housekeeping and the energy efficiency of lighting fixtures, rather than on reducing the lighting intensity in workplaces

The first step to reducing energy associated with lighting is to survey lighting in all locations of the brewery to assess the equipment, use patterns, and adequacy throughout the brewery. An investment in a lux meter (measuring lighting levels in lumens per m^2) will quickly pay off.

It needs to be mentioned again that measures taken to reduce electricity consumption by lighting systems helps reduce emissions from thermal electricity-generating stations. Refer to section 7 dealing with emissions.

Case study: Replacing standard fluorescent lighting with energy-efficient tubes

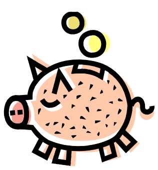
A brewery had 956 standard lamps (75 W, 8 feet), using them on average 8 hours a day, 5 days every week. They had a ballast factor of 1.1, electricity cost of $0.09/kWh and a demand charge of $13.60/kW per month. The use of high-efficiency lamps, saving 15 W per tube, generated annual savings of $5,140.

Immediate replacement would result (at a standard cost of $8.42 and a high-efficiency tube cost of $9.87) in a simple payback period of 1.8 years.

Incremental replacement of only those 17% of tubes that burn out annually would generate full annual savings only after six years. However, the incremental replacement generated a first-year simple payback of 3 months, second year of 1.6 months, etc., until all savings were completed in the sixth year.

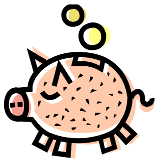
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Look up also items under section 8.2.1.
- Educate employees about good housekeeping practices; encourage change of wasteful habits; encourage employees to shut off lights when not required
- Assign responsibility for turning lights off at the end of the production day, and turning them on prior to the start of shift in each department and in general areas
- Ask Security or cleaning staff to ensure that lights are turned off
- Turn off fluorescent lights when they will remain off for at least 15 minutes
- Turn off high-intensity discharge lights when they will remain off for at least an hour
- Establish a regular cleaning schedule for lamps and shields of light fixtures – particularly in dusty environments (carton cutters, malt grist mill room, etc.)
- Institute a regular lamp-cleaning program that will maintain lumen output and reduce total lighting requirements.
- Implement a regular re-lamping program

Housekeeping, no or low cost



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- When re-lamping, it is most economical to change all the lamps at the same time
- Reduce or switch off unnecessary outside floodlights and signs
- Reduce parking lot lighting when not in use

Lamps get dimmer with age, yet continue to use the same power: re-lamp!

- Verify the light level in all brewery areas to insure adequacy, and eliminate excessive lighting levels (e.g., corridors, storage areas)
- Invest in a light meter (lux meter); it will quickly pay for itself
- Examine opportunities for de-lamping of excessively lit areas. When doing so, remove the ballasts for fluorescent and high-pressure sodium lighting as the ballast consumes electricity even when the bulb is removed
- Examine opportunities for reducing lighting hours
- Check the condition of the fluorescent tube protector tubing for yellowing and dirt
- Clean skylights, if applicable
- When installing new lighting, opt for a low-energy, high-efficiency types
- Use motion detector switches where an operator’s presence is intermittent and/or where feasible (storerooms, cellars, offices, etc.) to reduce power consumption
- Minimize lighting use in cooled areas as it adds to the heat lead
- Reduce lighting to the minimum safe level. Install motion detector switches on exterior security lighting

Medium cost

- Use motion-detector light switches where feasible, e.g., offices, storerooms, etc.
- Use a programmable or photocell-governed system or motion-detector light switches for general exterior lighting
- Reposition the lamps, the placement of which is not effective – e.g., when shining on top of stacked pallets, bales of hops, on top of tanks, to the pasteurizer or the soaker, etc.
- Install automatic lighting control by time clock that will switch off lights at predetermined times (with overriding provision for local areas)
- Provide adequate task-focused rather than general space lighting – i.e., reduce the level of general lighting to a minimum and provide task lighting at workstations, as required

Medium cost

(Continued)

- Where the environment permits it, paint the walls and ceilings with white or lighter colours and use the light reflectance to improve the brightness of the workplace
- Replace old ballasts with an energy-efficient type (especially important if power factor is low and the brewery pays penalties as a consequence)

Capital cost

- Replace lower-efficiency lighting with more efficient types (e.g., mercury lamps with HP sodium lamps)
- Replace all standard fluorescent tubes with high-efficiency tubes (T* series)
- Replace existing lighting with discharge and low-energy lamps whenever possible. In high-ceilinged areas, substitute fluorescent or mercury vapour lights for metal halide or sodium lamps
- Where conditions permit it, lower the ceiling lamps to increase light intensity o the floor; it may even lead to a reduction in the number of existing lamps

8.16 Electric motors and pumps

Electric motors:

The efficiency of older electric motors is generally much lower (as is the power factor) than that of the new generation of high-efficiency (HE) motors. The HE motors have efficiencies above 93% (in dependence on the motor horsepower: the higher, the better efficiency). The summary replacement of running old motors with the HE models is often difficult to justify, unless they run close to 24-hours a day and the power cost savings provide a good return on the investment. When the motors need to be replaced or sent for rewinding, HE motors should be purchased instead. (Provide cost-justification based on marginal motor cost difference, when the time comes for rewinding or replacement of the old motor.) This should be encoded in a purchasing policy.

Oversized motors or idling motors waste electricity and cause poor power factors. That is frequently the case in motors operating baghouses and air compressors – usually among the biggest in the brewery. These motors, among the hardest working, are especially susceptible to burnouts by electric induction or equipment harmonics.

Pumps:

In breweries, most pumps are electric motor-driven. Operating principles of pumps belong to one of two types:

- Centrifugal pumps (dynamic pumps) – add kinetic energy to the liquid to move it along (e.g., for water, wort, beer, wastewater)
- Positive displacement pumps – provide for a constant volumetric flow for a given pump speed, given by the volume of the pump cavities (e.g., for yeast slurry, diatomaceous earth slurry, wastewater sludge)

The design of a proper pump and its application is a complicated matter: both pumps and their drives must be large enough to overcome the resistance of pump drive, the conveying pipe network, of the pump seals and the elevation difference between the pump and the end user. All these main factors influence the power requirement of the pump in significant way.

Energy requirements – hence operating costs – can be reduced by selecting high-efficiency motors, pump and drives, tailored to operating conditions.

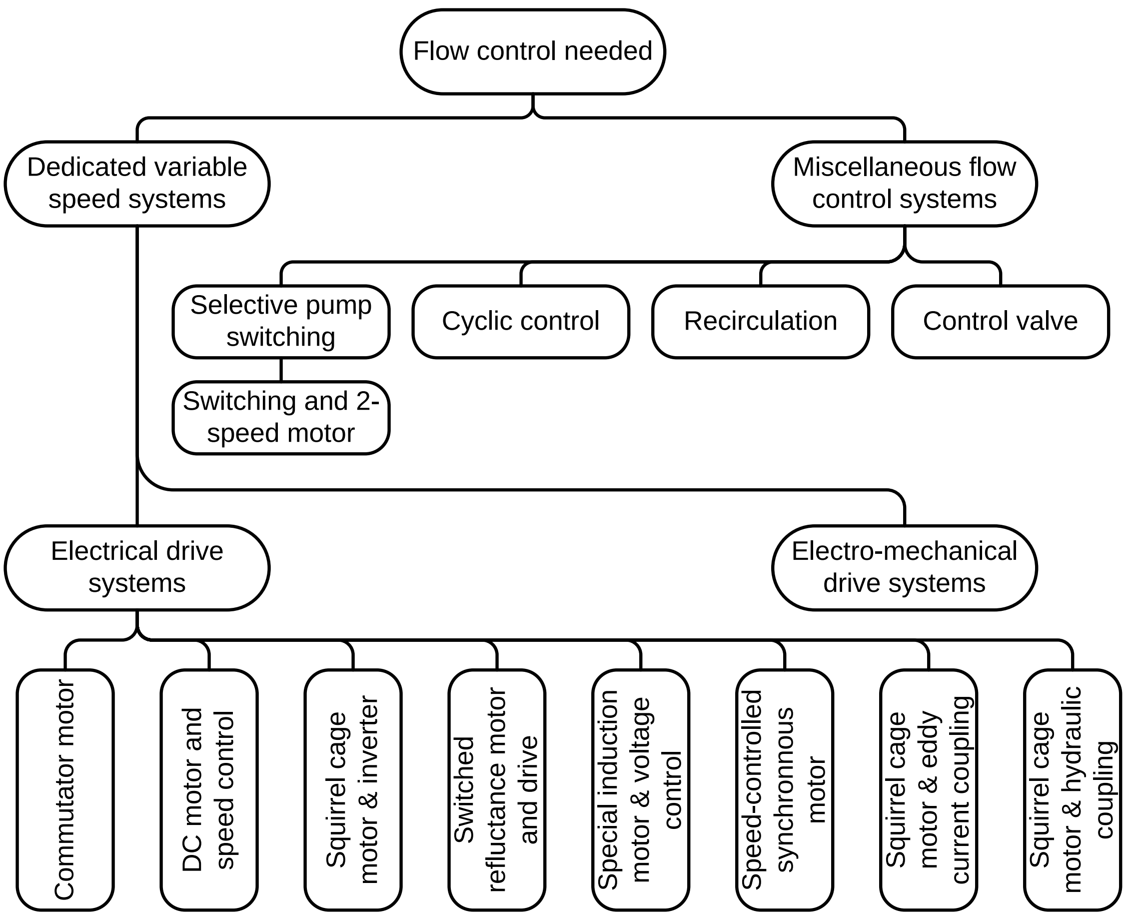
Pump seals also add to the frictional resistance of the shaft: the most common are mechanical and packing-gland seals. The latter requires up to six times the power requirement increase that the mechanical seals need. Pump seals, when they leak, not only contribute to losses. The leaks compromise the integrity of the system, and may contribute to oxygen pick-up and/or microbial contamination.

Pumps: (Continued)

Review the deployment of your pumps. They should be so sized as to fit the flow requirements. If the review shows that the pump is capable of producing more flow or head than the process requires, the following measures can be taken:

- When the flow load fluctuates, install a variable speed drive
- When the flow load is constant, reduce the size of the impeller on a centrifugal pump
- Optimize pump impellers (or change out) to ensure that the duty point is within the optimum zone on the pump curve.
- Maintain pumps through regular inspection and maintenance to monitor performance for an early indication of failure

Fig. 8.16.1 Options for energy efficient pump operation



As per CADDET Energy Efficiency Newsletter #2, 1995

Case study: Replacing standard drive belts on large motors with high-torque drive belts or energy-efficient cog belts

Every electric motor has some inherent inefficiency. Further losses are incurred on torque power transmission onto machinery by the use of a standard V-belt. Losses come from slippage, bending, stretching and compressing of the V-belt, which has a maximum efficiency of 94%, but under well-maintained conditions only about 92%.Replacing these with cog belts, which slip less and bend more easily than V-belts, or with belts with teeth in conjunction with replacing pulleys with sprocketed grooves (i.e., essentially “timing chains”) increases the efficiency of cog belts, conservatively, about 2% and high-torque drive belts (HTD) by at least 6%. Moreover, cog belts last about 50% longer than standard V-belts.

The following formulae are used in the calculations:

$$PS = (HP : \eta) \times LF \times S\text{; and}$$
$$ES = PS \times H\text{; where:}$$

PS = anticipated reduction in electric power, kW

ES = anticipated energy savings, kWh/y

HP = total horsepower for the motors using standard V-belts, kW

(1horsepower = .746 kW)

η = average efficiencies of the motors (e.g., 0.85)

LF = average load factor, %

H = annual operating time, h

S = estimated energy savings (e.g., 2% for cog belts, 6% for HTDs)

Using the electricity cost of $0.09/kWh and a demand charge of $13.60/kW per month., 16 motors totaling 152.5 HP operating 8 hours a day, 5 days a week, 52 weeks a year would have total annual power savings (consumption plus demand charges) of $1,040 for cog belts and $3,300 for HTD belts.

The simple payback is immediate for cog belts at replacement time.

Assuming an installation cost of $300 per set of pulleys, the simple payback for HTD in the above example is 1.5 years.

Case study: Using synthetic lubricants on large motors

A brewery with several large electric motors totaling 347.5 HP, with an average efficiency of 85%, an average load factor of 75% and one shift operating using synthetic lubricants would see a 10% reduction in energy losses. Using the consumption and demand rates from case study no. 5, it is possible to calculate electric power savings of $1,050 per year.

The potential savings in energy of changing to synthetic lubricants can be calculated using the following formulae:

$$PS = HP \times (1 - \eta) \times LF \times S$$
$$ES = PS \times H \text{ ; where:}$$

PS = anticipated reduction in electric power, kW

ES = anticipated energy savings, kWh/y

HP = total horsepower for the compressors and other large motors, kW

η = average efficiency of the motors (e.g., 0.85)

LF = average load factor, %

H = annual operating, h

S = estimated reduction of energy losses through lubrication, %

Synthetic lubricants carry a price premium. However, they last much longer than petroleum-based lubricants, which offset the increased costs. The only cost of implementation is the cost of a lubrication specialist. Assuming a cost of $800, the simple payback is 9 months.

Case study: Variable voltage, variable frequency inverters

Variable voltage, variable frequency (VVVF) inverters are well established in induction motor control. A Japanese 2.2 million hL/y brewery investigated the use of VVVF inverters for its 3,300 induction motors, used for pumping and other applications. The VVVF inverters allow pump motor speed to be continuously varied to meet load demand. The development of a standardized motor assessment procedure and detailed evaluation of 450 motors preceded a pilot installation. Five pumps with annual electricity consumption of 1,501 MWh were selected. After the VVVF inverters were installed, annual electricity consumption dropped to 792 MWh, a savings of 709 MWh. The corresponding payback was on average 1.9 years (at the time).

The project also investigated the effects of noise interference on surrounding equipment and carried out measures to alleviate any problems that occurred.

Case study: Turning off equipment (motors) when not in use

An audit of the packaging department revealed that many motors were running unnecessarily. Although demand spikes have to be avoided on restarting, consumption costs can be reduced by instructing personnel to make sure equipment runs only when necessary or by installing more sophisticated, automatic process controls.

Energy savings from shutting off the motors when not in use can be calculated using the following formulae:

$$ES = \{(HP \times CV) : \eta\} \times HR \times IL$$

$$CS = ES \times EC \text{ ; where:}$$

ES = realized energy savings, kWh/y

HP = horsepower of motors left on during the day, HP

CV = conversion factor (0.7459 kW/HP)

η = average efficiency of the motors, %

HR = annual hours of unnecessary idling time, h

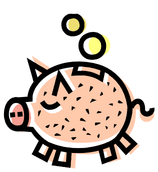
IL = idle load horsepower consumption of the motors (e.g., 10%)

EC = consumption cost of electricity, $/kWh

CS = cost savings

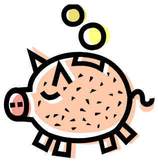
Other Energy management opportunities (EMOs) and tips:

Housekeeping, no or low cost



- Verify that motors are correctly sized for the job
- Switch off motors and equipment when not needed
- Install automatic controls for shutting down equipment when not needed
- Review motor burnout history and whether circuitries in the brewery need to be upgraded
- Use the electric utility as a resource: they can make suggestions as to demand reduction alternatives, points for metering, the way to measure consumption, possibly to loan an load analyzer
- Maintain and calibrate automatic controls on all equipment
- Control harmonic distortion passively and upstream: specify it in new equipment buying standards
- Check connections in the motor box for signs of overheating

Housekeeping, no or low cost



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- Perform regular vibration analysis of motors and drives
- Shut down pumps when there is no pumping requirement
- Ensure that packing glands on pumps are correctly adjusted
- Maintain clearance tolerances at pump impellers and seals
- Check and adjust motor driver regularly for belt tension ad coupling alignment
- Clean pump impellers and repair or replace if eroded or pitied
- Implement a program of regular inspection and preventive maintenance for motors, and all pump components to minimize failures

Medium cost

- Replace, as a matter of purchasing policy, old worn-out electric motors with new high-efficiency motors
- Install variable speed drives and soft-start options on electric motors
- Consider installing power load-shedding software in the electric motor control centres. (The software serves as an electricity and process management tool. It monitors power usage instantaneously and adjusts to a set target for maximum level of power it can use. It governs the consumption through a PLC. It can express real and predicted usage of power in kWh per unit of product and also in terms of costs; e.g., PowerPlusReporter® software; environmental and energy management programs from E2MS company)
- Consider conducting thermography inspections for detection of electrical hot spots, e.g., in a couplings and contacts, which indicate mechanical sources of losses (e.g., Fluke Co.'s heat detection gun can be used)
- Replace packing gland seals with mechanical seals
- Trim pump impeller to match system flow rate and head requirements

Capital cost

- Control harmonics that can interfere with and cause burnouts of motors. (The harmonics may cause damage to capacitors installed to control the power factor, trip fuses, burn motors and overheat equipment. It is essential to control harmonics. Examine your local conditions.)

Capital cost
(Continued)

- Consider replacing power capacitors with microprocessor-based LRC tuning circuits, sized for each specific equipment and power load, to control the power factor for improved savings (in some establishments power factors close to unity, of 0.98-0.99, are routine!)
- When installing an energy management system, choose one with both analytical and reporting capability
- Consider installing a power monitoring system, with monitoring and targeting methodology, to manage electricity consumption in the entire brewery
- Replace outdated / unsuitable equipment with correctly sized new units

8.17 Maintenance

The topic has been already mentioned in the text above, several times. Let us not overlook the energy benefits of preventive maintenance.

The costs of having to shut down production, because of equipment breakdown, can quickly add up:

- Loss of sales; loss of customer's confidence
- Higher labour costs that may include overtime to make up for lost time
- Higher overhead costs
- Extra energy cost to keep the line on stand-by, etc.

If you have not done it already, try to figure out the cost of various components of one hour of downtime. It is likely that its energy component will be substantial. Planned preventive maintenance can help to reduce the unplanned downtime, and should be a routine part of overall operations. Preventive maintenance, therefore, is a very important part of an energy conservation program and energy efficiency improvements in any brewery. The chances are that the investment in preventive maintenance will pay off very quickly in both operational and energy savings.

When preparing a preventive maintenance schedule, do not forget to also include hand tools (particularly compressed-air-driven ones). Apart from extending the useful life of the tools, it will result in a reduction of compressed air usage (thus, energy).

Predictive maintenance is one directed at avoiding failure within time specified by analysis of history data as probable for it to happen. E.g., "because the bearings on an electric motor fail typically every 15 months, on an average, the predictive maintenance will call for scheduled bearing replacement every 12 months."

Books have been written on setting up a preventive and predictive maintenance, and professional software programs for it, with various degrees of sophistication and tie-ins into other general management modules (such as accounting, purchasing, parts inventory and payroll areas) are commercially available. While these may be affordable for the bigger breweries, even the small ones may set up a simple preventive maintenance schedule and program using Excel or even Word processing softwares.

Case study: The importance of maintenance

Steam leakage:

A leak that emits a hissing sound and a hardly visible cloud of steam, e.g., a leaking steam valve, can result in a loss of approximately 1 kg of steam per hour. On an annual basis, it corresponds to fuel consumption of approximately 700 kg of oil or enough energy to produce 200 hL of beer at low consumption.

A leak that emits a hissing sound and a visible cloud of steam, e.g., a leaking seal, can result in a loss of 3 to 5 kg/h. This corresponds to fuel consumption of 2,100 kg to 3,500 kg oil per year, which is enough energy to produce 580 to 1,000 hL of beer at low consumption.

Missing insulation:

The insulation of just 1 m of 89 mm steam pipe used 6,000 hours per year will provide a savings of about 450 kg of oil per year, or enough energy to produce about 120 hL of beer.

8.18 Some brewery process-specific energy efficiency opportunities

Many examples of application of energy efficiency opportunities in Canadian breweries have been mentioned in the preceding text. Technological advances, albeit of no "radical breakthrough" nature, have been made by many brewery equipment manufacturers in the 12 years since this *"Guide"* has been published. Beer technology is mature and well established all over the world. Radical concepts of the 1960's and later years, such as continual brewing, continual fermentation and continual maturation of beer, have largely been proven as falling short of expectations that accompanied them.

The following is a brief list of the topics mentioned in the First Edition of the *"Guide",* re-published here **to stimulate thinking about application of not-so-novel-anymore, but workable technologies that can help the brewery reduce operating costs and outlays of energy, hence also improve the profitability of its operations.**

It is worthwhile to reflect on those items anew.

Combined heat and electrical power generation:

In the deregulated Canadian electrical energy market, the combined heat and power generation (CHP) may be interesting for some breweries. One Canadian brewing company, Labatt Brewery in London, Ontario, has adopted cogeneration, to take advantage of favourable Hydro policies at the time (1994). The technology is well-established and proven for application in many industries. Different types of turbines, running on various energy sources (natural gas, oil, but also waste, biomass, diesel and gasoline) are manufactured by many manufacturers. The power-to heat ratio of generation has been improving, nearing equity, and the total efficiency in the 80% range.

Other breweries may consider making the required large investment and its ROI potential of this attractive technology.

Wort boiling advances:

Attempts to optimize energy use and increase production efficiency led to various brewhouse technology modifications. For example, vessels were stacked up to reduce heat losses and pumping requirements; continuous mashing, separation and boiling processes were attempted; low pressure boiling was adopted by some; brew kettles were fitted with steam-heated coils and percolators to speed up and intensify wort boiling; external wort boilers were employed instead, etc.

Mechanical vapour recompression (MVR) and thermal vapor recompression (TVR) are proven, energy-efficient methods of brewing that has been employed worldwide. The methods regain a larger part of the latent vapours heat from the kettle, generated by boiling wort with exclusion of air. The heat obtained from the recompression of the vapours is re-used in the kettle heating. Capital-intensive additions to brewhouse equipment are required, but, depending on local circumstances, a relatively short return on investment can be obtained. Several major brewhouse equipment manufacturers

(Huppmann, Ziemann, Alfa-Laval and others) offer a variety of systems with varied degrees of sophistication that are currently in use in dozens of breweries around the world. One system, which uses a steam eductor, reduces kettle steam consumption by 50% and requires only a relatively small investment.

Other systems have been invented, e.g., microwave wort boiling (by Huppmann of Germany).

Nine years ago, Merlin™ thin-layer wort boiling technology by Steinecker Group has been planned by a brewery in Quebec. It claims many technological as well energy advantages, compared to conventional kettle boiling or low-pressure wort boiling. It appears that the Merlin™ wort boiling is a promising, state-of-the-art innovation that offers technological and product quality advantages, energy savings and environmental benefits in reducing the generation of greenhouse gases, consumption of water and generation of effluent.

Beer flash pasteurization:

Flash pasteurization is a not-so-new but seldom-employed method of beer pasteurization in North America. It can be used both for bottle packaging (often in combination with hot filling) and keg packaging. For breweries with well-controlled production and operating conditions, it may offer several major advantages, among them space and capital savings and savings of two-thirds on energy spent on pasteurization compared to the tunnel pasteurization process.

Tunnel pasteurization:

New developments have led to the application of automatic pasteurization unit control systems by several manufacturers (e.g., KHS, Sander Hansen, Gangloff-Scoma). New types of tunnel pasteurizers incorporate features designed to reduce water and energy consumption (e.g., “Channel Pasteurizer” developed by Sander Hansen).

Microfiltration and ultrafiltration:

With recent advances in the development of regenerable filtering media (cartridges and membranes) and separation technologies, microfiltration and ultrafiltration methods can be used. Their possible applications can include sterile filtration of beer (which obviates the need for energy- and water-intensive pasteurization), beer recovery, cleaning of spent caustic solutions from bottle washers and CIP systems, beer recovery, water conditioning, etc.

Spent yeast and spent grains drying:

Several new, tested and proven modern energy-efficient technologies for drying brewery by-products use different media such as saturated steam, superheated steam or direct gas combustion. These systems are available to supplant traditional inefficient drum-drying (spent yeast) or direct-fire drying (spent grains) generally employed by some large North American breweries.

Vacuum distillation:

A low-temperature distillation of CO_2 allows recovery of pure CO_2 from collection streams heavily contaminated with air. With this method, collection efficiencies can almost double in comparison with well-managed conventional collection methods and plants. Substantial energy and auxiliary raw material savings result.

Expert computer control systems:

An expert computer system uses specialist knowledge, obtained from a human expert (including well-experienced employees about to retire), to perform trouble-shooting, problem-solving tasks such as diagnosis, advice-giving, analysis and interpretation. By capturing and formalizing human expertise, such systems can improve the performance of businesses by:

- cutting the time taken to perform complex tasks, thereby improving productivity;
- reducing operation times;
- improving the quality of advice and analyses to enhance both operating efficiency and product quality; and
- making rare expertise readily available, thereby alleviating skill shortages.

Capturing this expertise should be considered before valued, experienced professionals retire from the brewery. These expert computerized control systems coordinate and optimize process operations. They are not yet extensively used but are commercially available. Examples of the applications include refrigeration and manufacturing controls especially linked to the use of brewery utilities. Their deployment in the monitoring and targeting system puts utility resource management on par with the management of any other resource in the brewery.

Replacement of PLC by PC process control:

Many individual programmable logic controllers (PLC) may have been replaced by fully integrated personal computer (PC) process control packages. The user profits from consistent, repeatable process control that eliminates programming of individual PLCs and integrates operations. Process changes can be executed simply from the PC, even remotely; records and past history are archived; motors can be turned on and off in response to pre-programmed material and product flows, levels, pressures, etc. Various packages, e.g., PCbrew™, PCflow™ and PCprocess™ have been made available. Their application in such areas as the boilerhouse, refrigeration, and packaging can assist energy saving efforts in the brewery.

9.0 APPENDICES

9.1 Glossary of terms

Only some of the terms used in the preceding text are explained here. For others, please view dictionaries, textbooks, professional literature or encyclopedias (e.g., Wikipedia at http://www.wikipedia.org)

Aerobic	Conditions in which air (oxygen) is present.
Anaerobic	Conditions in which there is no oxygen present.
Barm beer	Also called rest beer. That beer that remains within the mass of harvested yeast (usually high-gravity, high-alcohol beer) and which centrifugation or filtration may recover.
Blowdown	The maintenance of Total Dissolved Solids content in boiler water by draining small quantities either continually or intermittently from the base of the boiler to remove accumulated solids.
BOD	Biological oxygen demand. The standard test carried out at 20 °C over five days, for the measurement of water pollution in terms of the quantity of dissolved oxygen (mg/L) needed by microorganisms to break down biodegradable constituents in the waste water.
Carbon footprint	Environmental impact of operations on generation of greenhouse gases (GHG), expressed as carbon dioxide equivalent (CO_2e).
CCA	Capital cost allowances
CIP	Cleaning-in-place of brewing vessels, mains, road tankers, etc.
COD	Chemical oxygen demand. The measure of oxygen consumption, in mg/L, as supplied by hot acidified potassium dichromate, required to oxidize waste water components. It is always higher than BOD_5, which, for brewery waste water, is about 60%–70% of COD.
Condensate	Water produced by condensation of steam.
Condensing boiler	A boiler in which the water vapour produced by combustion is condensed to provide additional heat to the incoming water.

Dew point	The temperature at which air becomes saturated with water vapour and moisture starts to condense at a given pressure.
EAC	Energy-accountable centre; particularly in the context of Monitoring & Targeting methodology
Economizer	A heat exchanger that recovers energy from flue gas.
Emission	(In this context:) Pollution at the point of discharge.
EMO	Energy management opportunity – to save or conserve energy; the term is used in the text of this *"Guide"* frequently.
EMS	Environmental Management System. The part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.
EMT	Energy management team
GHG	Greenhouse gases – gases emitted by operations, that are implicated in global warming
GWP	Global Warming Potential (of various types of emission, all relating to CO_2e); the GWP of carbon dioxide, $CO_2 = 1.0$
HCV	Higher calorific value. The energy released from burning unit mass of fuel and when the resulting flue gas is condensed (also: gross calorific value or higher heating value).
High-gravity brewing	The practice of producing and fermenting wort at a higher concentration of dissolved solids (i.e., high gravity) than is required to package. The original gravity is adjusted by dilution with carbonated water prior to packaging, usually at the final filtration stage.
LCV	Lower calorific value. The energy released when unit mass of a fuel is burned and the flue gas is not condensed (also: net calorific value or lower heating value).
Make-up water	Water added to a boiler to replace condensate losses.

Mashing	The process of enzymatic hydrolysis that, upon mixing the malt grist with water and heating it following a preset program, converts malt starch into soluble sugars, producing (sweet) wort.
Maturation	Also called ‘aging’. Process of developing and stabilizing beer flavour and of beer conditioning.
Modular boiler	A boiler that may be combined with others of the same type supplying a common system. The number of boilers in use at any time depends on the demand load.
NAICS	North American industry classification system; each industry type has a discreet, assigned code.
Natural gas	Mostly methane, largely unprocessed earth gas.
Oxygen trim	A device that senses the oxygen content in the flue gas and controls the air-to-fuel ratio. Sometimes combined into a combustion efficiency monitor.
Pasteurization	The process of heating beer to destroy or inactivate micro-organisms capable of growing in it.
PDCA	The abbreviation of the words Plan-Do-Check-Act – the principle of continual improvement, pioneered by Dr. Edward Deming.
Peak demand	The maximum demand on electric power that occurs in a timed period, e.g., 15 or 30 minutes. An electric utility company may restrict this charge to certain times of the year (e.g., winter months) when the demand on distribution is at its peak. An integrating meter that sums up the consumption, records the maximum value and then resets to zero during every set period measures peak demand.
Power factor	The cosine of the phase angle between potential (volts) and current (amperes). Electric utility companies charge customers a cost penalty if the power factor is lower than a specified value, e.g., 0.93, since difficulties arise in supply and distribution systems if the power factor is significantly lower than unity.
Residual beer	Beer lost through various processes.
ROI	Return on investment

Saturated steam (Saturated water)	Steam or water at its saturation temperature.
Saturation temperature	The temperature at which water will evaporate or steam will condense, at a given pressure.
Sparging	Washing out of extract remaining in the spent grains by spraying water over it in the lauter tun.
SEC	Specific energy consumption; usually in MJ/hL
SWC	Specific water consumption; in hL water to hL beer ratio
Superheated steam	Steam at a temperature higher than the saturation temperature.
SS	Suspended solids. Solids that can be separated by filtration through a membrane.
VSD	Variable speed drive. A device to modulate the speed of the compressor to enable its ‘soft’ starts, reduce demand spikes in electricity, and flexibly respond to compressed air demand.

9.2 Energy units and conversion factors

Length	metre (**m**)
Mass	gram (**g**)
Time	second (**s**)
Temperature	Kelvin (**K**)

Commonly used temperature units: Celsius (**C**), Fahrenheit (**F**)

$0^oC = 273.15^oK = 32^oF$ $1^oF = 5/9\,^oC$ $1^oC = 1^oK$

Fahrenheit temperature = 1.8 (Celsius temperature) + 32

Note: To use the name "centigrade" instead of "Celsius" is incorrect and was abandoned in 1948 so as not to confuse it with a centennial arc degree used in topography.

Multiples:

10^1	deca (**da**)
10^2	hecto (**h**)
10^3	kilo (**k**)
10^6	mega (**M**)
10^9	giga (**G**)
10^{12}	tera (**T**)
10^{15}	peta (**P**)

Fractions:

10^{-1}	deci (**d**)
10^{-2}	centi (**c**)
10^{-3}	milli (**m**)
10^{-6}	micro (**µ**)
10^{-9}	nano (**n**)

Derived SI units:

Volume:	hectolitre (**hL**)	100 L
	cubic metre (**m^3**)	1000 L
Mass:	kilogram (**kg**)	1000 g
	tonne (**t**)	1000 kg
Heat:	Quantity of heat, work, energy	joule (**J**)
	Heat flow rate, power	Watt (**W**)
	Heat flow rate	Watt/m^2
	U value	Watt/m^2K
	Thermal conductivity	W/mK
Pressure:	Pascal (**Pa**)	

Conversion factors:

	Multiply:	by:	to obtain:
Length:	metre	3.2808399	feet
	metre	39.370079	inches
Mass:	kg	2.2046226	pounds
	tonne (t)	0.9842206	tons (long)
	tonne (t)	1.10233113	tons (short)
Volume:	L	0.219975	gallons (Imperial)
	L	0.264173	gallons (US)
	L	0.035315	cubic feet
Energy:			
Quantity of heat:	kWh	3.6	MJ
	kWh	3412	BTU
	MJ	947.8	BTU
	BTU	0.001055	MJ
Heat emission or gain:	W/m^2	0.317	BTU/ft^2
Specific heat:	kJ/kgK	0.2388	BTU/lb^oF
Heat flow rate:	W	3.412	BTU/h
U value, heat transfer coefficient:	W/m^2K	0.1761	BTU/ft^2h^oF
Conductivity:	W/m K	6.933	$BTU\ in/ft^2h^oF$
Calorific value (mass basis):	kJ/kg	0.4299	BTU/lb
Calorific value (volume basis):	MJ/m^3	26.84	BTU/ft^3
Pressure:	bar	14.50	lbf/in^2 (psi)
	bar	100	kPa
	bar	0.9869	std. atmosphere
	mm Hg (mercury)	133.332	Pa
	ft of water	2.98898	kPa

Specific volume:	m^3/kg	16.02	ft^3/lb
Velocity:	m/s	3.281	ft/s

Useful values:

1 Therm	=	100,000 Btu	or	29.31 kWh
1 ft^3 of natural gas	=	1,000 Btu	or	0.2931 kWh
1 US gal #2 oil	=	140,000 Btu	or	41.03 kWh
1 Imp. gal #2 oil	=	168,130 Btu	or	49.27 kWh
1 US gal #4 oil	=	144,000 Btu	or	42.20 kWh
1 Imp. gal #4 oil	=	172,930 Btu	or	50.68 kWh
1 US gal #6 oil	=	152,000 Btu	or	44.55 kWh
1 Imp. gal #6 oil	=	182,540 Btu	or	53.50 kWh
1 boiler horsepower	=	33,480 Btu/h	or	9.812 kW
1 mechanical hp	=	2,545 Btu/h	or	0.7459 kW
1 ton refrigeration	=	12,000 Btu	or	3.5172 kWh
1 beer barrel U.K.	=	1.6366 hL		
1 beer barrel Canadian	=	1.1365 hL		
1 beer barrel US	=	1.1735 hL		
1 MJ	=	0.278 kWh		
1 kcal	=	4.18 J		
1 kWh	=	1.168 Mcal		

In Canada, the value of 1 Btu (60.5^{o}F) = 1.054615 kJ was adopted for use in the gas and petroleum industry. The ISO recognizes the value of 1.0545 kJ.

"Rule of thumb" conversion – use for quick illustration in propagating the energy conservation efforts in your plant:

1.0 MJ equals:

- the energy content of about one cubic foot of natural gas, or
- the energy consumed by one ordinary incandescent 100 Watt bulb burning for almost three hours, or
- one horsepower electric motor running for about 20 minutes.

To **convert kBtu/USbarrel to kWh/hL** use the conversion factor 0.25 kWh/hl/kBtu/barrel.

To **convert kBtu/USbarrel to GJ/hL**, use the conversion factor 0.0009 GJ/hL/kBtu/barrel.

Grid electricity – consider greenhouse gas emissions generation on the average as **1 kg CO_2e / kWh**

9.3 Global warming potential of greenhouse gases (GHG)

Calculating reductions in greenhouse gas emissions

Although the following examples may seem specialized, the method used to calculate emission reductions applies to any energy management project that reduces consumption of fuel or electricity.

Case study: calculate emissions for on-site combustion systems

Use the data in Table 1 and the information given below to calculate the amount of CO_2, CH_4 and NO_x produced by combustion systems in the following example. To perform this calculation for your own facilities, obtain precise data from your natural gas utility.

- In a large brewery, the original natural gas burners in the boilers were retrofitted with high-efficiency burners. Annual fuel savings are estimated at 5 terajoules (TJ). What would be the corresponding reductions in CO_2, CH_4 and NO_x emissions?

- The emission factors for natural gas fuel are CO_2: 49.68 t/TJ; CH_4: 0.13-1.27 kg/TJ; NO_x: 0.62 kg/TJ. A range of 0.13-1.27 kg/TJ has been indicated for CH_4, so we will assume 0.6 kg/TJ for this calculation.

CO_2 reduction	CH_4 reduction	NO_x reduction
= 5 TJ/yr x 49.68 t CO_2/TJ	= 5 TJ/yr x 0.6 kg CH_4/TJ	= 5 TJ/yr x 0.62 kg NO_2/TJ
= 248.4 t/yr	= 3 kg/yr	= 3.1 kg/yr

Table 9.3.1.1: Greenhouse Gas Emission Factors by Combustion Source

Fuel type	CO_2		CH_4		NO_x	
Gaseous fuels	**t/ML**	**t/TJ**	**kg/GL**	**kg/TJ**	**kg/ML**	**kg/TJ**
Natural gas	1.88	49.68	4.8-48	0.13-1.27	0.02	0.62
Still gas	2.07	49.68	-	-	0.02	0.62
Coke oven gas	1.60	86.00	-	-	-	-
Liquid fuels	**t/kL**	**t/TJ**	**kg/kL**	**kg/TJ**	**kg/kL**	**kg/TJ**
Motor gasoline	2.36	67.98	0.24-4.20	6.92-121.11	0.23-1.65	6.6-47.6
LPGs	1.11-1.76	59.84-61.38	0.03	1.18	0.23	9.00-12.50
Diesel oil	2.73	70.69	0.06-0.25	1.32-5.7	0.13-0.40	3.36-10.34
Light oil	2.83	73.11	0.01-0.21	0.16-5.53	0.13-0.40	3.36-10.34
Heavy oil	3.09	74.00	0.03-0.12	0.72-2.88	0.13-0.40	3.11-9.59
Petroleum coke	4.24	100.10	0.02	0.38	-	-
Solid fuels	**t/t**	**t/TJ**	**g/kg**	**kg/TJ**	**g/kg**	**kg/TJ**
Anthracite	2.39	86.20	0.02	varies	0.1-2.11	varies
US bituminous	2.46-2.50	81.6-85.9	0.02	varies	0.1-2.11	varies
CDN bituminous	1.70-2.52	94.3-83.0	0.02	varies	0.1-2.11	varies
Sub-bituminous	1.74	94.30	0.02	varies	0.1-2.11	varies
Lignite	1.34-1.52	93.8-95.0	0.02	varies	0.1-2.11	varies
Coke	2.48	86.00	-	-	-	-
Fuel wood	1.47	81.47	0.15-0.5	0.01-0.03	0.16	8.89

Abbreviations: t, tonne; kg, kilogram; g, gram; ML, megalitre; TJ, terajoule; kL, kilolitre; GL, gigalitre.
(See Appendix 5.1: Energy units and conversion factors.)

Source: *Voluntary Challenge and Registry Program Participant's Handbook*, August 1995, and its addendum, issued in March 1996. Data supplied by Environment Canada.

Case study: calculate the impact of reductions in electrical consumption

Energy management projects that reduce electrical consumption also have a positive effect on the environment. However, the emission reductions occur at the electrical generating station rather than at the site of the efficiency improvements. To calculate the emission reduction, use the method outlined above, and then calculate the energy saved at the generating station. This is done by adjusting the figure representing energy saved at the site to account for losses in the electrical distribution system.

Using Table 9.3.1.2 and the information given below, calculate emission reductions. To perform this calculation for your own facilities, obtain precise data from your electrical utility.

- At a large manufacturing plant in Saskatchewan, the energy management program involved replacing fluorescent light fixtures with metal halide fixtures and replacing several large electric motors with high-efficiency motors. The total annual energy saving was 33 600 MWh. Calculate the corresponding reduction in emissions.
- Table 3 shows that, in Saskatchewan, the average CO_2 emission from electrical power generation is 0.82 t/MWh.
- Convert to equivalent energy saving at the generating station using a transmission efficiency of 96%.

Annual energy savings at generating station:
= 33 600 MWh : 0.96 = 35 000 MWh/yr

CO_2 reduction:
= 35 000 MWh/yr x 0.82 t/MWh
= 28 700 t/yr

Table 9.3.1.2

Average CO_2 Emissions for 1998, by unit of electricity produced
(the table is used for demonstration only, actual figures may have changed since)

	t/MWh	t/TJ
Atlantic Provinces	0.25	68.4
Québec	0.01	2.5
Ontario	0.23	65.2
Manitoba	0.03	8.2
Saskatchewan	0.83	231.7
Alberta	0.91	252.1
British Columbia	0.03	7.4
Northwest and Yukon Territories	0.35	98.5
Canada Average	0.22	61.3

Source: 1996 survey of utilities by the Demand Policy and Analysis Division, Office of Energy Efficiency, Natural Resources Canada

9.4 Energy efficiency opportunities self-assessment checklist

The following is a list of sample questions to answer when establishing the current status in your brewery.

More questions may be formulated from the ***EMOs*** in the preceding sections.

Use the following audit questions as a guide (mark an “X” in the box if an action is required)

Management:

☐ Does the brewery have an energy policy? Are all employees aware of it?

☐ Does the brewery have an environmental management system (EMS) in place?

☐ Are employees involved in EMS activities?

☐ Are operators involved with the quality management system?

☐ Have employees been educated/trained about the significance of energy and utilities conservation and correct use practices?

☐ Are operators involved with the energy and utilities conservation efforts?

☐ Are employees aware of energy and utilities costs and the level of these expenditures in the plant?

☐ Is there a system in place to communicate the results of energy and utilities conservation efforts to employees?

Electric power demand:

☐ Is the load profile known?

☐ If not, has the local utility or a consultant been contacted for help?

☐ Is there a system in place to prevent the load from exceeding a given value during peak billing hours?

☐ Can equipment presently being run during peak demand periods be re-scheduled to off-peak times or to other peak times when load is low?

☐ Can some non-essential equipment be shut off during peak demand periods by use of timers or production operators?

Consumption:

- ☐ Is there a procedure to shut off production equipment and auxiliary production equipment when not in use?
- ☐ Has it been implemented?

Power factor:

- ☐ Is the power factor, as noted on the electrical bills, less than 90%?
- ☐ Is there a billing penalty for poor power factor?
- ☐ If so, do you monitor how much it costs you?
- ☐ Have you considered means and equipment to improve the power factor?

Fuels:

- ☐ Would it be possible to use a cheaper alternative source for thermal energy?
- ☐ If natural gas is used, have the costs of uninterruptible versus interruptible supply been evaluated?

Fuels/material storage:

- ☐ Is heating in the area controlled and is temperature being maintained at the minimum acceptable level for a raw material store?
- ☐ Are the cold storage room adequately insulated and the doors well sealed to minimize heat loss?
- ☐ Is the passageway to cold storage areas fitted with flexible aprons to isolate it from warmer areas?
- ☐ Are heated oil tanks and associated piping adequately insulated?
- ☐ Is the oil heated at the correct temperature?
- ☐ Are the outside syrup (if used) storage tanks and associated piping adequately insulated?
- ☐ Is the external insulation watertight?

Boilers and steam distribution:

- ☐ Is boiler efficiency checked on regular basis?
- ☐ Is the efficiency level acceptable for the type of boiler and fuel being used?

Boilers and steam distribution: *(Continued)*

- ☐ Is the boiler fitted with a dual capability to use natural gas or fuel oil to take advantage of interruptible gas supply contracts?
- ☐ In multiple boiler installations, how is the steam demand matched to boiler deployment?
- ☐ How is it done on weekends and in non-production periods?
- ☐ Are the flue gases checked for CO_2 and oxygen content on regular basis? Are they within an acceptable range?
- ☐ What is the flue gas temperature?
- ☐ Is a flue gas heat recovery system being used?
- ☐ Is there any evidence of soot buildup on the fireside surface of the boiler?
- ☐ Is the flame in the combustion chamber bright and clear and does it fill the combustion chamber without impingement?
- ☐ How is the blowdown rate controlled? How regularly?
- ☐ What is the blowdown rate and is it at the level recommended by water treatment specialists?
- ☐ Is it based on the dissolved solids content of the boiler water?
- ☐ Has the dissolved solids content been calibrated to conductivity?
- ☐ Is there a system in place to recover heat from the blowdown?
- ☐ Is waste oil from process equipment burned in the boiler?
- ☐ Is there redundant or oversized steam piping causing excessive heat loss?
- ☐ Are steam lines, flanges, valves, condensate lines, etc., adequately insulated?
- ☐ Is there evidence of steam or condensate leaks?
- ☐ Is the condensate return rate adequate and is it being verified?
- ☐ Are steam traps the correct type for the application being used?
- ☐ Is there an adequate maintenance program for the inspection, repair and replacement of steam traps?
- ☐ What percentage of traps is found to be faulty?
- ☐ Is there a program in place to remove scale from heat transfer surfaces of equipment?

Cooling water:

☐ Are there opportunities to reduce the quantity of cooling water being used?

☐ Is a re-circulated water-cooling system being used?

☐ Is there any evidence of process cooling water being dumped to the sewer?

☐ Can any parts of the cooling system be converted from single-pass to multi-pass?

☐ Is the flow of cooling water at the various production processes being varied according to cooling requirements?

☐ Is the cooling water at production processes shut off when the process stops?

☐ Can any heat be usefully re-used from the cooling system?

☐ Is there a routine maintenance procedure to de-scale cooling surfaces and cavities?

Process water:

☐ Is the water to beer produced ratio measured and reported routinely?

☐ Has water usage in the entire brewery been reviewed?

☐ Have all opportunities for re-using process water been examined from the point of view of double or multiple re-use?

☐ Have all processes been evaluated for such re-use?

☐ In cleaning operations, is low-pressure, high-volume hosing down used instead of the other way around where it is possible?

☐ Is high-pressure, small-volume sluicing of the whirlpool trubs practiced?

☐ Are hoses left running in the cellars, wasting water and adding to the refrigeration load?

☐ Is the post-filler water spray station tied in with the filler operation?

☐ Are eye showers left running as a source for cool drinking water?

☐ Is any hot water being put to the drain?

☐ Are there any quantities of perfectly usable water being dumped?

Compressed air:

☐ Are there any opportunities to reduce or eliminate compressed air use in any of the processes?

☐ Is it possible to replace any compressed air-operated components with hydraulic or electric linear power?

Compressed air: *(Continued)*

☐ Identify the part of the process that requires the highest air pressure.

☐ Can another source of power be used to enable the compressed air system pressure to be reduced?

☐ If not, can it effectively operate at lower air pressures?

☐ Is there a system to control compressor sequencing according to the demand for air?

☐ Are compressors shut down when production is shut down?

☐ Is the intake for the compressors coming from the coldest location?

☐ If air is used to cool the compressors, is it exhausted outdoors during summer and used to heat during winter?

☐ Is heat being recovered from the compressor cooling water?

☐ Is there evidence of water in the system?

☐ Is there evidence of air leaks?

☐ What method is used for leak detection?

☐ Is there a routine program for inspection of leaks?

☐ Is compressed air used to blow off debris and dust accumulation from surfaces?

Refrigeration:

☐ Is there a regular inspection and testing program in place for the refrigeration system?

☐ Does it include a review of the system's controls and set points for evaporating and condensing temperatures?

☐ Is there a regular maintenance program in place?

☐ Are the compressor COP and the overall system COP measured regularly?

☐ Is the refrigeration plant-operating regimen reviewed frequently to reflect changing beer production and weather conditions?

☐ Is the refrigeration equipment operating during peak demand hours?

☐ Is there an inadequate or excessive defrosting of evaporators?

☐ Are they iced-up often?

☐ Are there de-stratification fans in high-ceilinged refrigerated areas?

CO2 collection and use:

☐ What is the brewery's CO_2 balance: purchase vs. generation?

☐ What is the pattern of usage? Is the usage metered and known?

☐ What governs CO_2 collection from the fermenters?

☐ How well controlled is the carbonization of beer and dilution water?

☐ Are there many instances of beer or dilution water reprocessing/dumping?

☐ Is alkaline solution-based cleaning done in the CO_2 atmosphere?

Emissions:

☐ Have you performed carbon footprinting of your operations?

☐ Are you aware of the values, their financial price and have you considered them for emission trading?

Electric motors:

☐ Is there a policy to replace old motors with energy-efficient (high-efficiency) motors?

☐ Is there a policy to replace smaller motors with energy-efficient motors?

☐ Is a rewind versus replacement evaluation made when motors fail?

☐ Are there any motors running at less than 50% of their rated capacity?

☐ Are motors checked for hot spots (bearings, contacts in connection boxes...)?

Brewery envelope:

☐ Is the wall insulation adequate? Is there evidence of frost or condensation on the inside of external walls?

☐ Is the roof insulation adequate (snow melts quickly on a poorly insulated roof)?

☐ Has a thermograph analysis of the building envelope (and of the process insulation) for potential heat loss locations been considered?

☐ Are windows single glazed? Is there broken/cracked glass?

☐ Are there gaps between the walls and window frames?

☐ Are east, south or west-facing office windows using reflective glass or fitted with reflective foil or with shades?

☐ Are external doors being left open for "ventilation"?

***Brewery envelope**: (Continued)*

- ☐ Are the employees aware that such a practice negates air conditioning throughout the year?
- ☐ Are external doors free from drafts when closed?
- ☐ Are frequently used doors (such as the main entrance) designed to minimize air movement in and out of the building?
- ☐ Are doors at loading docks fitted with dock seals?

HVAC:

- ☐ Is HVAC equipment shut down when buildings are unoccupied?
- ☐ Has the use of a central computerized HVAC and lighting management system been considered?
- ☐ Are thermostats used to control building temperatures and are the temperature settings appropriate for the type of work being carried out?
- ☐ Are setback temperatures used when buildings are unoccupied?
- ☐ Are thermostats tamper-proof?
- ☐ Are paint booths, soakers, and carton shredders fitted with exhaust fans?
- ☐ Is the fan use coupled with the equipment use?
- ☐ Is the balance between intake and exhaust air satisfactory?
- ☐ How do you know?
- ☐ Is the volume of fresh air intake excessive?
- ☐ Is there a way to reduce levels when the production is stopped or working at lower levels?
- ☐ Is there any problem with stratification, particularly in winter?
- ☐ Has the use of ceiling fans for air circulation been considered?
- ☐ Can any process heat or exhaust heat be recovered to heat incoming fresh air?
- ☐ Is there a cheaper alternative energy source for heating?

Lighting:

☐ Are lights left on when not needed?

☐ Do observations during non-working times need to be made?

☐ Are there areas that are over-lit?

☐ Are there areas that are under-lit?

☐ Are dimmers used to match lighting levels to the task being performed?

☐ Is lighting switched off when the building, storage areas, offices, etc., are unoccupied?

☐ Have motion sensor switches been considered?

☐ Can outside security lighting be controlled by motion sensors?

☐ Are lights clean?

☐ When ordering replacement bulbs, are the most energy-efficient bulbs specified?

☐ Do you know which the energy-efficient types are?

☐ Can any of the lighting systems be replaced with more energy-efficient systems?

Mill room:

☐ Are dust extraction systems fitted with variable drives? (Ask this question for any other motor-driven equipment.)

☐ Are the dust collectors inspected/cleaned regularly?

☐ Is steam used only when conditioning malt (if used for that)? Any leakage?

☐ Is the setting of grist mills and malt grist composition checked regularly?

☐ Are the mill rollers inspected and re-grooved regularly?

Brewhouse:

☐ Is there adequate ventilation of the brewhouse in the summer?

☐ Has the installation of a kettle stack economizer been considered?

☐ Has the hot water been balanced for the entire brewery?

☐ If a stack scrubber for odour control is being used, is the spray water recycled?

☐ Is there an effective program for cleaning scrubber fill (saddles)?

Wort cooling:

☐ Are the heat exchange surfaces de-scaled frequently enough?

☐ How often is the heat exchanger taken apart and inspected?

☐ Has heat reclamation from the wort cooler been considered?

Fermenting and yeast room:

☐ Is CO_2 –removing ventilation in the fermenting room tied to actual CO_2 readings to prevent excessive evacuation, especially in the summer?

☐ Is water use for tank flushing and floor rinsing minimized?

☐ Is the refrigeration equipment ice-free?

☐ Is the use of stirrers in the yeast tanks intermittent?

Aging and finished beer cellars:

☐ Is the cellar's ambient temperature checked regularly?

☐ Are the cellars well insulated?

☐ Is outside air infiltration prevented, especially in the summer?

☐ Conversely, could outside low temperatures be taken advantage of in the winter?

☐ Is beer cooling excessive?

☐ Is the use of water for floor rinsing minimized?

☐ Are stationary beer pumps in the packaging cellar insulated for sound and heat?

Packaging department:

☐ Is it possible to reorganize operations by moving product packaging from less efficient lines to more efficient lines in order to shut down a complete line?

☐ Is the operation of conveyors linked to the operation of the filler?

☐ Has the optimal pasteurization (number of P.U.) been determined?

Warehouse, shipping and receiving:

- ☐ Is heating in the area controlled and is the temperature being maintained at the minimum acceptable level?
- ☐ Are air seals (curtains, aprons) used around truck loading doors?
- ☐ Are measures in place to prevent ingress of ambient heat from packaging areas into refrigerated areas?
- ☐ Are loading doors closed when not in use?
- ☐ Can lighting levels be reduced?
- ☐ Is high-efficiency lighting being used?
- ☐ If electric forklift trucks are being used, are batteries charged in off-peak times?

By-products:

- ☐ How is the waste beer collected and disposed of? Is it eliminated from the wastewater stream?
- ☐ How is the spent diatomaceous earth (“filter aid”) disposed of?
- ☐ Can it be segregated from the wastewater stream?

Solid waste:

- ☐ Is the waste segregated by type (glass, cardboard, wood, etc.)?
- ☐ Are there separate collection containers available throughout the plant?
- ☐ Have employees been educated and trained about the issue?
- ☐ Could some solid waste types be given away (plastic barrels, firewood, contaminated glass for road building)?
- ☐ Could some be sold (crown boxes, uncontaminated glass cullet, aluminum cans, metal scrap)?
- ☐ Could some be recycled (work gloves, protective clothing)?
- ☐ Has the use of a compactor been evaluated?
- ☐ Is the solid waste weighed on site before haul-away?
- ☐ Has the current waste disposal contract been competitively evaluated?

Wastewater and treatment:

☐ Has there been a review of the separate wastewater streams to quantify their loading with a view to reduce or eliminate contamination at the source?

☐ Has there been a review of the history and trend of effluent surcharges?

☐ Is the wastewater combined stream metered? If not, has the formula for calculating it been reviewed? Does it include brewhouse evaporation?

☐ Is wastewater regularly sampled for pH?

☐ Have suspended solids and oxygen demand been evaluated?

☐ Have the results of municipal sampling been verified in the plant or through independent and certified laboratories?

☐ Has the use of surplus, non-liquefiable brewery CO_2 or flue gases been considered for pH control of the brewery effluent?

☐ If treated on site aerobically, is aeration efficient? Is it geared to BOD/COD loading, temperature?

☐ Have fine-bubble diffusion systems been evaluated?

☐ How is sludge disposed of?

☐ If treated anaerobically, can the methane gas be burned off in the boiler or used to preheat intake air?

Maintenance:

☐ Is there a formalized preventive / predictive maintenance program in place?

☐ Are equipment checklists used for preventive maintenance?

☐ Is there good instrumentation to measure operating parameters (temperature, pressure, flow rates, compressed air losses, etc.)?

☐ Is the measuring and monitoring equipment regularly calibrated or its function otherwise verified?

☐ Are gauges calibrated on a regular basis?

☐ Is operation equipment fitted with automatic time and temperature controls?

☐ Is there sufficient instrumentation and recording equipment to enable employees to set up equipment correctly and to enable maintenance and engineering staff to troubleshoot?

☐ Are synthetic lubricants used in gearboxes, compressors, etc.?

9.5 “Best practices” in energy efficiency as volunteered by small brewers

“Best practices” in energy and utilities conservation as currently implemented in the small breweries of the participants and related in the 2010-02-12 conference call, sponsored by the Brewers Association of Canada.

BAC and the authors of this *“Guide”* were pleased by this unvarnished listing, as it showed the emergence of grass-root efforts – however simple some of them may sound – to improve the energy efficiency in the industry. We think and hope that these examples in the *“Guide”* will stimulate also others to get involved.

The volunteered information, loosely categorized, is listed below. Case studies furnished by the brewers have been extracted and inserted into appropriate chapters, e.g., Compressed air.

Boilers / Steam:

- The comprehensive review of boilers, particularly the retrofitting of the burners brought the NO_x emissions down to California standards.

- The examination of the steam plant standard operations resulted in operating it at a lower pressure, and the boilers were further optimized to in-plant use during brewhouse operations and after the brewing finished.

- Consider the separation of process and heating steam and condensate return systems so that heating loops can be isolated during non-heating periods.

Refrigeration:

- The optimization of suction and discharge pressures resulted in substantial savings, currently being quantified.

- The use of Variable Speed Drives (VSD) for ammonia condensers for chilling optimized the power use.
- The energy efficiency measures in refrigeration resulted in 1.6 M kWh savings. Our discharge pressure is approximately 90 psi all winter, the set point based on wet bulb temperature. VSD and slide valve control result in optimum compressor efficiency and the VI ratio correction ensures we are not over-compressing.
- Use the heat rejected by your refrigeration system to heat your space, especially if you are in a cold climate. The refrigeration system has to work in the winter anyway, so the heat rejected can be ‘free’ but for the capital investment. Not always an easy retrofit, but easy to do at start-up, and can be an option should equipment replacement or retrofit be necessary.

Refrigeration: (Continued)

- When designing a plant or investing significant capital, cross cutting is a great opportunity. We use ammonia waste heat to preheat boiler feedwater and are looking at other opportunities (e.g.,) to expand CO_2 from liquid to gas. This is easier done with new infrastructure but the opportunity is certainly there.
- Consider implementing an oil inventory management program (in refrigeration) to track the amount of oil added and drained from the system. We had in the past (an instance) where an oil separator was not doing its job and we were getting far too much oil carrying over to our process equipment.
- Incondensables represent a huge loss. A good way to check this is to measure the temperature of the discharge ammonia from the condenser at the bottom of the discharge elbow and then correlate that to a pressure and compare that to the head pressure you are running – the difference is what the non-condensable gas is adding.

Compressors - air:

- Compressed air leaks are a killer … try to find the time to make the repairs as soon as possible after you find one.

Energy management / people issues:

- For the small, large and medium-sized companies under one corporation, the integration of energy targets with salaried staff was effective as an important means to improve engagement and address staff time considerations.
- It was suggested that it would be useful for a smaller brewer to pay attention to water and energy use and where losses are occurring, and that this would provide an important basis for taking action. However, the lack of baseline data could make it difficult to assess performance.
- Two small brewers noted that for them a lack of manpower presented a key challenge to organized, systematic effort to improve energy efficiency.
- The importance of raising awareness was illustrated on a hugely successful employee contest to identify and fix leaks (compressed air, steam).

Lighting:

- The use of natural lighting complemented by spot lights where required, as well as making use of outside weather for cooling and heating, provides savings.

Water:

- Mass balance -water in Brewhouse: by improving the water balance in the Brewhouse and supply the excess 10% of water used for flushing, we expect to be able to drastically make up water that required steam to heat up. By putting larger volumes of water through the wort cooler, we were also able to decrease the temperature set point of the brewing water prior to wort cooling (40^{0}F to 45^{0}F or higher). This will also have a significant impact on cooling load on the water when it comes in at 72^{0}F during the summer.
- Our keg washing system utilizes a recirculation tank with a strength meter that allows us to reuse a cleaning solution over and over until the metered strength falls below an established threshold.
- One of the biggest areas we conserve energy at our brewery is through heat regeneration in the cooling of our wort. The hot wort is passed through a heat exchanger that exchanges the heat with cold water that is used for cleaning, brewing and sterilizing.
- When cleaning multiple tanks we reuse cleaning solution between more than one tank to reduce chemical usage and energy costs from hot water.
- Automated CIP, focus on chemical analysis (titration checks), led to reducing water consumption.
- Water reuse through re-circulation and water recapture led to lowered water to beer ratio in the brewery down to 4.5 : 1 region.

Buildings / HVAC:

- Put all exhaust fans on some kind of control, not a manual switch that can be left on. It can be a spring wound time, a dehumidistat, and thermostat…just something that will only allow the fan to run when needed.
- Don't bring in outdoor air when you don't need it and don't exhaust conditioned indoor air when you don't need to.
- Make the minimal investment in setback thermostats. Keep the office areas cool when not occupied (or warm in the summer) and keep the production area cool all the time to reduce heat loss to outdoors and heat loss from aging tanks to the space.
- Keep the heat in one place and the cold elsewhere…keep all overhead doors well weather-stripped, including a keg fridge door, insulate all hot and cold piping and repair damaged sections promptly, maintain edge seals on dampers so that they close tightly.
- The brewing area is heated in the winter by the ambient heat given off by the brewing process.

Buildings / HVAC: (Continued)

- Letting climate work for you, opening up cellars to outside in the winter for free cooling.

- Cooling with external air in winter was possible when the temperature gradient was at least 10^{o}C.

Miscellaneous practices:

- We are in the process of obtaining energy controllers that will capture and store energy from our systems during peak performance to be utilized later under less strenuous conditions.
- Recycle whenever and wherever you can…we wash dirty bottles in a bottle washer rather than use new, we use folding trays for bottles and cans rather than use glued/stapled trays so that we can refold them if they are in good shape, we have introduced a refillable beer filling system where people bring in a 1.9 litre jug and get it refilled over and over with draught beer (our customers LOVE it).

9.6 Specific primary energy savings and estimated paybacks

In the preceding, particularly in the section 8, the Energy Management Opportunities – EMOs – were divided in three categories, with the estimation of the investment intensity and payback period. Perhaps the following will summarize for an energy manager of a plant manager, what actual savings and payback one can expect from measures taken either in the brewery process, or in improving utilities efficiency. The table is reprinted, with grateful acknowledgement, from the report *"Energy efficiency improvement and cost saving opportunities for breweries – an ENERGY STAR® Guide for energy and plant managers"*; by C. Galitsky et al., Ernest Orlando Lawrence Berkeley National Laboratory and the U.S. Environmental Protection Agency, 2003".

Although a bit dated, and relating to not-too different U.S. conditions, the following tables are still useful as an indication of the expected magnitude of improvements /reductions, and thus can serve in project selection. The tables have been modified to show the effect of primary energy savings expressed in MJ/hL (instead of the original kBtu/barrel (US)).

9.6.1 Specific primary energy savings and estimated paybacks for process-specific efficiency measures

Process specific			
Process area	**Measure**	**Payback in years**	**Primary energy savings[A] in MJ/hL**
Mashing and lauter tun			
	Waste heat recovery	n/a	Limited data
	Use of compression filter	2	17
Wort boiling and cooling			
	Vapour condenser	<2 to 5	<1 – 20
	Thermal vapour recompression	>2	14 – 16
	Mechanical vapour recompression	D	21
	Steinecker Merlin system	2	28
	High gravity brewing	<1	12 – 20
	Low pressure wort boiling	n/a	29 – 36
	Wort stripping	n/a	18 - 38
	Wort cooling	3	15
Fermentation			
	Immobilized yeast fermenter	n/a	Limited data
	Heat recovery	>2	Limited data
	New CO_2 recovery systems	>2	Limited data
Processing			
	Microfiltration	2 to 4	Limited data
	Membranes (alcohol-free)	4	17
	Heat recovery-pasteurization	n/a	1
	Flash pasteurization	n/a	5 – 13
Packaging			
	Heat recovery washing	<3	5
	Cleaning improvements	3.4	21

Notes:

[A] Primary energy savings account for savings in fuel use, electricity use and electricity transmission and distribution losses. We use a conversion factor of 3.08 from final to primary electricity use, based on average U.S. power plant heat rates. Energy savings are primarily taken from data from case studies in the literature. To convert kBtu/US barrel to kWh/hL use the conversion factor 0.25 kWh/hl/kBtu/barrel. To convert kBtu/US barrel to GJ/hL, use the conversion factor 0.0009 GJ/hL/kBtu/barrel.

[B] Based on data from two sources (EIA, 1997; Beer Institute, 2000), we assume an average U.S. brewery fuel usage of 212 kBtu/barrel (53 kWh/hL0, 90 to 100% of the fuel used in the boilers, and an average boiler conversion efficiency of 85%.

[C] We estimate a total plant electricity consumption of 122 kBtu/barrel (30.5 kWh/hL, or 110 MJ/hl), (EIA, 1997).

[D] Results vary widely, depending on plant configuration and size of the brewery

n/a Paybacks for this measure could not be estimated from available data

9.6.2 Specific primary energy savings and estimated paybacks for efficiency measures for utilities

Utilities			
Process equipment / utilities area	Measure	Payback in years	Primary energy savings[A] in MJ/hL
Boilers and steam distribution[B]			
	Maintenance	<1	4
	Improved process control	<1	3
	Flue gas heat recovery	>3	2
	Blowdown steam recovery	2.7	2 – 3
	Steam trap maintenance	<1	3
	Automatic steam trap monitoring	<1	<1
	Leak repair	<1	5
	Condensate return	>1	17 – 19
	Insulation of steam pipes	1	5 – 25
	Process integration	D	42 - 76
Motors and systems using motors[C]			
	Variable speed rives	2 to 3	5 – 22
	Downsizing	2	1 – 2
	High efficiency	1 to 2	1 – 2
Refrigeration and cooling[C]			
	Better matching of cooling capacity and cooling loads	3.6	1 – 2
	Improved operation of ammonia cooling system	5.5	<1 – 2
	Improved operations and maintenance	<1	4
	System modifications and improved design	≤3	5 – 7
	Insulation of cooling lines	n/a	Limited data
Other utilities			
	Lighting	<2 to 3	2 – 5
	Reduce space heating demand	n/a	7
	Anaerobic waste water treatment	≤5	5 – 8
	Membrane filtration wastewater	<1 to 5	Limited data
	Control and monitoring systems	3.5	<1 -33
	Combined heat and power (CHP)	4	60 – 90
	CHP with absorption cooling	5	71
	Engine driven chiller systems	2 to 4	11

Notes:

[A] Primary energy savings account for savings in fuel use, electricity use and electricity transmission and distribution losses. We use a conversion factor of 3.08 from final to primary electricity use, based on average U.S. power plant heat rates. Energy savings are primarily taken from data from case studies in the literature. To convert kBtu/US barrel to kWh/hL use the conversion factor 0.25 kWh/hl/kBtu/barrel. To convert kBtu/US barrel to GJ/hL, use the conversion factor 0.0009 GJ/hL/kBtu/barrel.

Notes: (Continued)

[B] Based on data from two sources (EIA, 1997; Beer Institute, 2000), we assume an average U.S. brewery fuel usage of 212 kBtu/barrel (53 kWh/hL0, 90 to 100% of the fuel used in the boilers, and an average boiler conversion efficiency of 85%.

[C] We estimate a total plant electricity consumption of 122 kBtu/barrel (30.5 kWh/hL, or 110 MJ/hl), (EIA, 1997).

[D] Results vary widely, depending on plant configuration and size of the brewery

n/a Paybacks for this measure could not be estimated from available data

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At the same time, the literature listed may serve as **sources of additional or detailed information.**

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The use of the above-listed sources is also recommended to any reader wishing to obtain further information.