ENERGY *guide*

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Brewers Association of Canada

A Joint Project of
The Brewers Association of Canada,
Natural Resources Canada
and the
Canadian Industry Program
for Energy Conservation (CIPEC)

Energy Efficiency Opportunities in the Canadian Brewing Industry

Lom & Associates

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Lom & Associates, the authors of this guide, are active in the fields of environmental consulting and training, implementation of ISO 9000 quality management systems and ISO 14001 environmental management systems, and ISO 14001 auditing. The firm has specialized practical knowledge of the Canadian and international brewing industry spanning 33 years.

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FOREWORD

Energy Efficiency Opportunities in the Canadian Brewing Industry is a joint project of the Brewers Association of Canada, Natural Resources Canada and the Canadian Industry Program for Energy Conservation (CIPEC). The objective of this guide is to acknowledge data related to industrial energy use in the Canadian brewing industry and the opportunities for energy efficiency improvements within the sector.

CIPEC consists of 19 task forces representing various industrial sectors in Canada. The Brewing Industry Sector Task Force is comprised of representatives from several brewing companies and is currently (spring 1998) headed by the Chair of the Environmental Committee of the Brewers Association of Canada, Ralph Backman of Labatt Breweries of Canada.

CIPEC task forces act as focal points for identifying energy efficiency potential and improvement opportunities, establishing energy efficiency targets for each sector, reviewing and addressing barriers, and developing and implementing strategies for target achievements.

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. The Brewers Association of Canada initiates and promotes industry policy aimed at enhancing the competitiveness of the brewing industry. Energy efficiency is recognized as a means of reducing investment in energy supply to save companies money without sacrificing energy service. By increasing internal efficiency through investment in energy efficient technologies and practices, companies can reduce their operating costs and increase competitiveness.

This guide is a practical demonstration of the Brewers Association of Canada's commitment to reduce greenhouse gases in support of the federal government's environmental objectives and international undertakings. By highlighting energy opportunities for the brewing industry, the guide will also help in the development of the sector's energy efficiency target and in the drawing up of an action plan to realize this target.

Among Canadian breweries, good energy practices are accepted as being simply good business practice. However, 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.

This guide presents data, new ideas and tips for energy efficiency improvement. It also offers a rationale for the sound management of energy and utilities within the larger management of breweries.

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Disclaimer

1.0 INTRODUCTION

> ***The business of business is to stay in business.***
> ***Peter Drucker***

Time is the most important element in any organization's energy efficiency initiative. Time lost in starting an energy efficiency program will never be recovered. Opportunities lost through procrastination cost money. For example, if a brewery that has a $1.0 million annual energy budget could make a 10% improvement in the first year, 5% improvement the next year and 3% in the third year, it would save, at current interest rates, about $514,000 over the period. However, if it delays the start of the program for three years, it will *cost*, cumulatively, about the same $514,000 This example serves to illustrate why, in the current economic climate of ever-increasing competition and shrinking margins, it pays to examine how a brewery manages its energy and utilities costs and to do something about it – now.

Breweries are large energy users The overall specific consumption of energy used in a brewery, usually expressed in megajoules per hectolitre of finished product (MJ/hL), will vary with the mix of package types, processes and equipment employed. the brewery's size, age, layout, geographical location, and the overall level of efficient energy utilization. Because of these variables, it could be misleading to compare one brewery's energy consumption with another. What is important, though, is that every brewery strives to improve its energy consumption ratio within its limitations and means. This guide applies to all small and large Canadian breweries.

Among the proven, tested energy- and money-saving methods that this guide describes are:

- Procedural changes
- Employee involvement
- Common-sense good housekeeping
- Energy audits
- Maintenance improvements
- Operational changes and/or control
- Minor capital investment
- Major capital investment
- Continual improvement through monitoring and targeting

For the sake of conciseness, the reader is assumed to be familiar with brewery operations and to have a basic understanding of the brewery's various technical and process aspects of energy use and utilities.

The guide gives brief descriptions of energy efficiency opportunities, tips and examples, as well as an implementation guide for an energy and utilities conservation program. More in-depth information is identified in the bibliography and list of recommended reading (Appendix 5.3) and in the Glossary of Terms (Appendix 5.1). Space limitations necessitated omitting many detailed calculations of energy and utilities savings which are usually quite complex and require explanations. However, some examples of the calculations are shown in Appendix 5.6; others are contained in the listed literature.

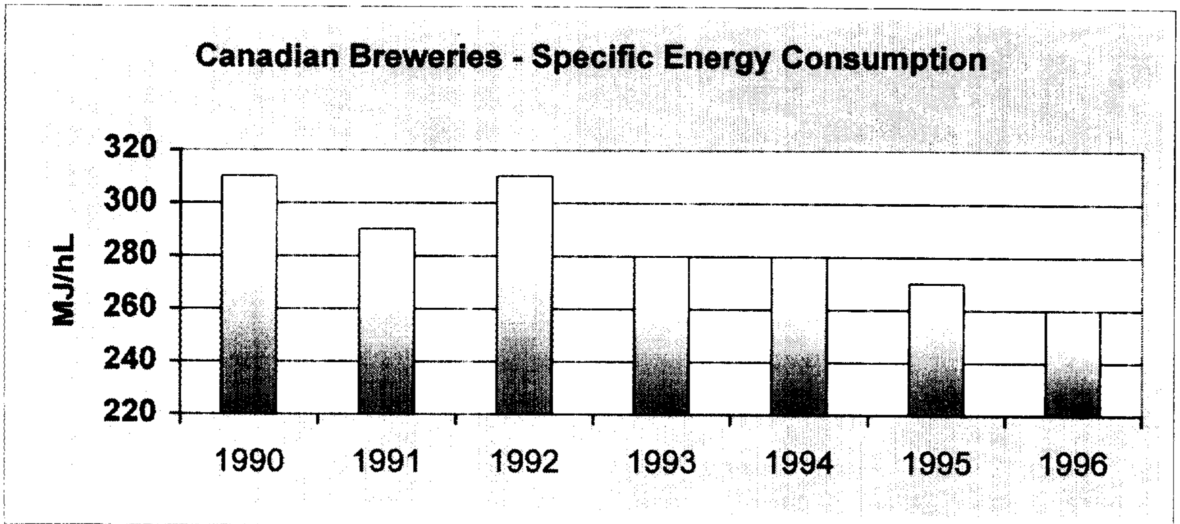
A brewery that improves its energy efficiency will profit financially and benefit from the favourable public image of being an environmentally conscious, good corporate citizen. Therefore, an integration of energy efficiency improvement efforts with an environmental management system will also be described briefly.

1.1 BREWING SECTOR PROFILE

Approximately 75 breweries of all sizes currently operate in Canada (Spring 1998). After rapid production growth in the 30 years following World War II, combined output levelled and has averaged 22.5 million hectolitres (hL) annually for several years (BAC data). Changing demographics and lifestyles and other influences have led to decreases in per capita beer consumption. In the last decade, competition in the Canadian brewing industry was further complicated by free trade with the United States. All this led to efforts aimed at reducing costs, including structural changes within the Canadian brewing industry. Increased productivity, improved efficiencies and new strategies have been pursued; many breweries have made efforts to improve energy and utilities efficiencies and help the environment at the same time.

Brewers in Britain were the first to initiate energy efficiency improvements. The stimulus was provided by the Suez crisis in 1973. The results were impressive. In 1976, specific energy consumption was 303 MJ/hL. A 1978 survey of 88 breweries showed a reduction to 266 MJ/hL, and in 1992 to 197 MJ/hL. U.K. breweries currently average 180 MJ/hL. Other nations soon joined in the conservation effort. They may have more difficulty than the U.K. achieving such low levels due to a different product mix. In the U.K, almost 80% of beer is produced in the low-energy consuming form of draught beer (more than anywhere else in the world); the remainder is split evenly between bottles and cans.

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. The Task Force soon started to yield results. Average specific energy consumption, formerly well above the 350 MJ/hL mark started to drop. (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.) In 1996, the Canadian average was 260 MJ/hL, with individual breweries (particularly in relatively balmy Vancouver) starting to drop below 190 MJ/hL.



In today's brewing industry, energy consumption values of 150 MJ/hL in energy (fuel) and 30 to 45 MJ/hL in electricity (totaling 180 to 195 MJ/hL) are considered low.

The types of products and their packaging, as well as the efficiency with which energy is utilized, influence specific energy consumption (SEC). A considerable amount of work has been done in small breweries (production up to 500,000 hL per annum) in the U K. to determine "practical minimum" and "best practice" SEC target figures. SEC target values for varying ratios of large (i.e., keg, casks, and tank) to small (i.e., bottles, cans and PET) product packaging in small breweries are as follows:

Large Pack (%)	Small Pack (%)	SEC Target Practical Minimum (MJ/hL)	SEC Target Best Practice (MJ/hL)
100	0	93	200
90	10	99	220
75	25	108	250
67	33	112	257
50	50	122	300

"Best practice" figures are proposed as intermediate targets for small breweries and are intended as a step towards achieving the "practical minimum" SEC. Small breweries already operate at or near these target levels.

Best practice energy efficiency (BP%) can be calculated as follows:

$$BP\% = \frac{\text{Predicted energy use} \times 100}{\text{Actual energy use}}$$

Predicted energy use is obtained by multiplying the actual departmental production volumes (in hL) by the energy ratios stated below and then adding together all the separate amounts.

Actual energy use is calculated from specific energy values obtained from source materials such as utility bills.

The following table, which shows results of a U.K. effort to quantify best practice (BP) energy efficiencies of various operations and processes in small-sector breweries, provides useful information on where to direct conservation efforts.

A Guide to Best Practice Energy Efficiency (BP%) Calculation

Department	Energy Ratio*	Notes
Brewing and fermentation	74	-
Cooling and filtration	9	-
Packaging		
Keg	33	Include volume in total packaged volume (TPV)
Cask	11	Include volume in TPV
Bottle	200	Include volume in TPV
Can	13	Include volume in TPV
PET	20	Include volume in TPV
Bulk tank	3	Include volume in TPV
Retail tank (drop-in)	36	Include volume in TPV
CO_2 recovery	1000	Multiply ratio by tonnes (t) CO_2 recovered
Administration	17	Multiply ratio by TPV

*The energy ratio represents the proportionate energy consumption of an individual operation/process from overall brewery energy use. As such, the energy ratio is not expressed as a unit of measure.

A small brewery, knowing the cost of energy per MJ, can then calculate the savings that would result when the target figures are achieved.

1.2 Information Review

The following sources complemented the development of this guide:

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Refrigeration fault diagnosis system in Joshua Tetley Brewery, U.K., Best Practice reports, Energy Efficiency Office, Ministry of the Environment, U.K., 1992.
Case study: Moosehead Breweries Ltd., Canadian Electric Association, 1987.
1997 Directory of Efficiency and Alternative Energy Programs in Canada, Energy Efficiency Branch of Natural Resources Canada, 1997.

2.0 ENERGY EFFICIENCY OPPORTUNITIES

2.1 BREWERY PROCESSES AND ACTIVITIES

Brewing is an energy-intensive process that uses large volumes of water and subjects product-in-process twice to heating and cooling.

Malt, made of malting-grade barley, is brought to the brewery, stored in silos, 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 malt grain envelope). Sometimes the crushing is preceded by steam conditioning of the grain; sometimes wet crushing is employed. In the mash tun, grist is mixed with warm water 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) by straining in a false-bottomed lauter tun. The residual extract in the spent grains is sparged out with hot water, and the sweet wort is boiled in a kettle with hops. 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. The metabolism releases much heat that has to be removed by chilling the fermenter contents. At the end of the fermentation, the resultant green beer is chilled to 0°C 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. Green beer is rid of suspended yeast by centrifuging or by settling in the storage tank. During the transfer to and in the storage tank, it is further chilled, depending on its alcohol content, to as low a temperature as possible, usually to –1.0°C to –2.0°C. After a (flavour) maturation period ("lagering"), the beer is filtered once or twice, carbonated and is ready for packaging into bottles, cans or kegs in the packaging cellar.

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. The pasteurization process consists of heating the packaged beer to 60°C. Pasteurization kills or inactivates microorganisms that could bring about beer spoilage. Pasteurization takes place primarily in tunnel pasteurizers where 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 exit temperature of about 30°C.

Packaged beer is stored in a warehouse. Warm beer, particularly if the oxygen content is higher than it should be, does not keep its flavour (shelf life) well over time. Ideally, therefore, warehousing should be brief to avoid the necessity of cooling the warehouse.

2.2 Energy and Utilities Costs and Management

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.

A well-run brewery would use from 8 to12 kWh electricity, 5 hL water, and 150 MJ fuel energy per hectolitre 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.

In Canada, the major utilities cost categories are electricity, natural gas/oil fuel, and water. Their proportion of overall utility expenditures (1991 data) can be approximated as follows:

Proportion of Overall Utility Expenditures

Energy source	% Total
Electricity	46.5
Natural gas	31.3
Diesel fuel	11.8
Gasoline/kerosene	4.7
Other (liquified petroleum gas, coal, coke, etc.)	3.5

The CIPEC Brewery Task Force estimates that, on average, a brewery could potentially save:

• Electricity:	5.7%	Payback in 1.6 years
• Natural gas:	15.0%	Payback in 1.8 years

The various areas where these savings can be made are described later.

Where breweries lack the necessary internal resources to conduct an energy use analysis and develop plans for improvement, investment in a consulting firm will almost certainly pay off. The Ontario Ministry of Environment and Energy calculated from the 557 energy analyses it funded (1992), that there was, on average, a return of 12 to 1. That is, on every dollar spent on an energy audit, $12 was identified in potential savings.

Utility management is an ongoing concern in any brewery. Successful utility management depends on a team effort starting with a firm commitment from the Plant Manager and his or her management team. Management's demonstration of support filters through the organization to every employee. Education of employees and cultural change within the organization must accompany the effort and be sustained in order to achieve lasting energy efficiency improvements.

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. These days, because breweries often have narrow profit margins, energy and utilities management may be vitally important. Despite the fact that 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.

Some of the reasons why savings have not been realized even when the opportunity for savings is so great are:

- Lack of awareness of opportunities that exist.
- Don't know what to do.
- No senior management support ($, time, change).
- Energy/utilites not a priority.
- No money/staff available.
- No accountability.

To realize opportunities, brewery management must successfully mesh organizational change, behavioural change, and new energy use technology.

To provide a focus, accountability and responsibility for energy efficiency efforts, competent members of the brewery's technical staff (such as engineers, stationary engineers, the engineering manager) should be designated. Their duties, operating support, budget etc., should be clearly defined. The results of their work should be reported regularly and directly to the top brewery management. Energy and utilities costs should be viewed as an important part of a brewery's controllable costs. Suitable communication of results to all employees is necessary to foster their personal interest and involvement. The effort will pay off.

With the stated goal of achieving energy savings of 35%, it is possible to calculate a brewery's profit margin increases for various profit margin percentages of a brewery, and various energy cost percentages. The percentages of profit margin increases are shown in the table below.

Profit Increase From Energy Savings

If the original profit margin is:	And if a brewery'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%

Energy and utilities management is based on the principles of monitoring and targeting (M&T), to be discussed later. In M&T, energy and utilities consumption is measured and considered in relation to production figures. Once the system has built sufficient history, these specific consumption figures – key data – are analysed and compared with energy and utilities consumption targets and recent consumption. Since each energy-accountable centre (EAC) "buys" energy and utilities from the energy centre (powerhouse), the lowest possible consumption is encouraged to minimize losses and improve efficiencies of operations.

Canadian Energy Management and Environment Training Program

The Canadian Energy Management and Environment Training Program (CEMET) was established in 1992 through the partnership of Natural Resources Canada, the Canadian Gas Association and the Canadian community colleges in Ontario through Durham College in Oshawa. In addition to being a training program, CEMET also serves as a network of energy management contacts and resources. It provided several intensive, two-day courses dealing with energy management issues, such as:

- Boiler systems
- Steam and condensate systems
- Heating, ventilating and air conditioning
- Furnaces, dryers and kilns
- Energy auditing
- Electrical energy management opportunities workshop

Other courses focus on

- Lighting systems
- High-efficiency motors
- Metering and monitoring
- Refrigeration
- Waste heat recovery
- Cogeneration
- Performance contracting
- Energy management for senior decision-makers

The national network incorporates community colleges, technological institutes and CEGEPs (in Québec) across the country as partners. In excess of 160 schools participate, providing accessibility to courses in all regions of the country. Courses can be held at designated training locations as well as on-site for industry groups. (The activities of CEMET have largely been assumed by Energy Training Ontario; see Appendix 5.5 for contact information).

2.3 Measurement as a Basis for Improvement

> **Measurement is the *first* step that leads to control and eventually to improvement.**
> **If you can't measure something, you can't understand it.**
> **If you can't understand it, you can't control it.**
> **If you can't control it, you can't improve it.**

Measurement is the basis for the U.K. Brewers' Society (now Brewers and Licensed Retailers Association) M&T energy and utilities management system. 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.

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. While the concept is relatively new in Canada, at least one large brewery, Molson in Etobicoke, Ontario, implemented M&T with impressive 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.

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 analysing 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 setting 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, a 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:

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:	
Refrigeration	Consumption/ GJ cooling
Steam production	Consumption/ GJ heat
Air compressors	Consumption/ Nm^3 air
CO_2 collection	Consumption/ kg treated CO_2
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:

Installation of Energy and Utilities Meters

Meters	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
Compress. air				X	X					
CO_2			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. A schematic diagram of M&T implementation is contained in Appendix 5.7

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

2.4 FUELS AND ELECTRICITY SUPPLY

2.4.1 Fuels supply

Most Canadian breweries operate their boilers on dual fuel, usually natural gas and oil. The exceptions may be in regions such as Newfoundland that are not served by natural gas pipelines The obvious advantage of having a dual fuel supply is the assurance that a brewery will not have its operations halted easily by delivery interruptions of one type of fuel. 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

<u>Comparison of Fuel Types</u>

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

Fuel Type	Advantages	Disadvantages
Liquified 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°C • needs power source for evaporation at low temperatures
Heavy oil ("Bunker oil")	• 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 (NO_X) • high sulfur content may preclude utilization of flue gas economizers due to corrosion problems arising from condensation and formation of acids from sulfur oxides (SO_X) • very viscous, needs insulated and heated storage tanks and pump/pipe delivery systems

Fuel Type	Advantages	Disadvantages
		• 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°C	• gels in extreme cold • Waxes may precipitate in cold weather • may clog filters • requires heat tracing • other general comments similar to heavy oil

Other fuels, such as coal, coke and wood, although used elsewhere, are not generally used 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 (predominantly methane with heavy contamination with CO_2) has variable composition and calorific content and is an unreliable energy source as the principal fuel. However, it can be used to supplement the use of other fuels, such as in preheating of return condensate or air intake, or water heating. Because it is wet, corrosion of the supply system may be a problem.

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, have to be evaluated. As most of the boiler plants in Canadian breweries are well over 30 years old – originating in the boom times of the 1950s and 1960s – these considerations will come into play when deciding on a retrofit or replacement of the aging plant.

⇨ Tips:*

Low or No Cost (payback period is six months or less):

- ✓ 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
- ✓ Inspect and repair insulation
- ✓ 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

2.4.2 Electric Supply

Breweries in Canada buy their electric power from public utilities, with the exception of a single brewery, which employs in-house generation. Although the scope for price bargaining is limited, there are opportunities for obtaining special tariffs. There are three ways a brewery can reduce costs without necessarily reducing energy consumption:

- Reduce the peak demand.
- Move energy-consuming operations to off-peak times such as night or weekend, to take advantage of lower kWh rates.
- Where there is a power factor billing penalty, increase the power factor.

The maximum demand (peak demand) usually forms a spike of limited duration when a number of operations are running (starting) concurrently. The spike determines the rate for the entire peak time period (e.g., from 07:00 h to 23:00 h). In other words, if the peak demand was 1000 kW, but through rescheduling, it could be reduced to 600 kW, the demand charge savings amount to 40%. Demand reduction will not save energy *per se*, but due to the electrical utility's billing policies, it will save money. (See also in Appendix 5.6, Examples of Cost-Saving Measures in Some Brewery Areas, case study no. 10.)

Moving energy-consuming operations to off-peak times can generate additional savings on the energy consumption portion of the electrical bill. By simply managing the time when electricity is being used, considerable savings are possible.

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* "Tips" appear throughout this Guide and are organized according to subject matter. Consult other sections for quick tips on related topics. See also Appendix 5.8, "Energy Efficiency Opportunities Self-Assessment Checklist".

The power factor is calculated as follows:

$$\text{Power factor} = \frac{\text{kilowatts (resistive power)}}{\text{kilovolt-amperes (resistive plus reactive)}}$$

Remember that the resistive component of the electric power does the useful work. Inductive loads such as under-loaded AC induction motors, transformers, welding machines, induction heating coils and lighting ballasts normally cause low power factors.

An electric utility can install metering equipment to measure kilovolt-amperes (kVA) as well as kilowatts and bill the brewery for the larger of actual kW or 90% of kVA.

A brewery with energy management controls in place may be able to save up to an estimated 20% of its current billing through load shifting, load shedding and power factor correction.

TIPS:

Low or No Cost (payback period is six months or less):

- ✓ Identify large consumers of electricity (e.g., refrigeration compressors, air compressors) and list them together with the related percentage of total electricity usage
- ✓ 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 analyser 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:
  - good housekeeping (educate employees first) – switching off lights and equipment when not needed or in use
  - installing motion detectors to govern lighting
  - 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

- 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.

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

✓ Replace (especially large) standard electric motors with high-efficiency types when replacement is necessary
✓ Install variable speed drives and improved controls. 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

Capital Cost (new equipment required; payback 3 years or more):

✓ 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 (particularly in large breweries)

2.5 Boilers and Steam Distribution

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 about 25% to 35% 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.

2.5.1Boilers

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.

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.

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 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.

2.5.2 Steam distribution

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. The economic consequences of not having pipe insulation installed are shown in Case Study No. 13, in Appendix 5.6.

Leakage:
The cost of steam leakage is often not realized. Examples of the fuel penalty from typical leaks in a 7 bar g system are shown in the following table:

Steam Leakage Losses

Leak Size Diameter (mm)	Steam Loss tonne/year	Fuel Used tonne/year
0.80	12	0.8
1.60	48	3.4
3.20	180	12.6
6.40	732	51.2
9.50	1680	118.0

Every brewery can assess the cumulative effect of several leaks and the cost, given the rate it pays for fuel.

Heat transfer:
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 generate the steam may be lost. As well, costs increase for the purchase and treatment of make-up water.

TIPS:

Low or No Cost (payback period is six months or less):

- ✓ Identify and correct steam and condensate leaks
- ✓ Properly insulate steam and condensate return lines and components
- ✓ Set up a steam trap maintenance program to ensure optimum performance, and reduce downtime of steam systems
- ✓ 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%
- ✓ 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 gen-

erated to energy units [kJ or Btu]. Boiler efficiency will be the ratio of the two)

- ✓ Check flue gas oxygen and carbon monoxide levels regularly with a manual (chemical Orsat) or automatic flue gas analyser. 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
- ✓ Avoid dynamic operation – review brewhouse kettle boil control and steam valve operation
- ✓ Choose low-pressure operation during non-production periods
- ✓ Compress the brewing schedule in the low production periods to avoid stops and starts of large boilers
- ✓ 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

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

- ✓ 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
- ✓ Consider using steam-powered condensate return pumps instead of electrically powered ones
- ✓ 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

- ✓ 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
- ✓ Replace incorrectly selected steam traps with the correct type for the service

Capital Cost (new equipment required; payback 3 years or more):

- ✓ If used in pasteurizers and soakers, consider replacing live steam injection that consumes water and necessitates make-up and heating with heat exchangers
- ✓ 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°C drop in flue gas exit temperature will improve boiler efficiency by 1%
- ✓ Install local high-efficiency boilers that respond rapidly to load demands

2.6 Refrigeration and Cooling Systems

In a typical brewery in Canada, over 30% of electric power is consumed by refrigerating and cooling systems. Because the refrigeration plants commonly use 20% or more energy than they need, optimizing their function represents a major energy conservation opportunity.

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:

- 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.
- Stationary engineers and operators may lack training in refrigeration efficiency.

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. Overcooling 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°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°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).

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.

Analysing 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 are 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°C increase in condensing temperature will increase costs by 2% to 4%.
- A 1°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.

⇨ TIPS:

Low or No Cost (payback period is six months or less):

- ✓ Brewery operators may not understand efficiency issues – educate and train them
- ✓ Operation and maintenance issues need to be constantly addressed; an inefficient operating mode may be more convenient to the operator
- ✓ 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.
- ✓ 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.
  - In refrigerated rooms, use as little water as possible (remember that one gallon of water needs a ton of refrigeration of energy to evaporate)
- ✓ 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. Eliminate ingress of moisture into the cooled space (from ambient air and from water hoses)
- ✓ 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
- ✓ Adjust the cooling plant's evaporation temperature to about –6°C to –8°C, to cool beer to about –2°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
- ✓ 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

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

- ✓ 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 closed-loop system for cooling compressors and condensers
- ✓ Replace inadequate doors to cold areas
- ✓ Install traps to remove oil and water from the ammonia. Contaminants in the ammonia raise the boiling point

Capital Cost (new equipment required; payback 3 years or more):

- ✓ 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 electrical energy 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

2.7 COMPRESSED AIR

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 $0.05 per kWh.

Cost of Leaks

Hole Diameter	Air Leakage	Cost Per Month
1 mm	1.0 L/s	$10
3 mm	10.0 L/s	$111
5 mm	26.7 L/s	$298
10 mm	105.0 L/s	$1,182

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.

TIPS:

Low or No Cost (payback period is six months or less):

- ✓ Commit to a brewery-wide awareness program
- ✓ Generate compressed air at the pressure required; never generate at too high a pressure only to reduce it to a lower operating pressure
- ✓ Use intake air from the coolest location, probably by direct ducting of fresh intake air from the outside
- ✓ In air-cooled compressors, discharge outdoors during the summer and use indoors for space heating during winter
- ✓ Check that the system being operated is not faulty (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, install 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 (retrofit of equipment or buildings required; payback period is 3 years or less):

- ✓ 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 (new equipment required; payback 3 years or more):

- ✓ Evaluate installation of a combustion engine-driven compressor 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
- ✓ 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

2.8 Process Gases

CO_2, and sometimes nitrogen, 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. 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 attenuated. Therefore, the fermenter yield of CO_2 is about 4 kg from one hectolitre of 12°P wort, or about 6 kg/hL from 18°P 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/°P. 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 liquifiable, 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 taint in it.

A recent development allows collection of CO_2 with gross air contamination (e.g., 20%) and the recovery of 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 liquifaction 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., Wittemann). 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-liquifiable CO_2 from fermenters may find a wide range of uses in a brewery, among them neutralization of brewery effluent, vessels' blanketing, etc.

TIPS:

Low or No Cost (payback period is six months or less):

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

- ✓ 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_2 consumption
- ✓ Evaluate the replacement of CO_2 with nitrogen where it makes sense
- ✓ Consider CO_2 recovery from storage and buffer tanks

Capital Cost (new equipment required; payback 3 years or more):

- ✓ 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 online 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

2.9 Utility and Process Water

Breweries are huge consumers of water. Specific water usage is expressed as a ratio of water volume purchased (or used, if on a private well) to volume of beer produced. In Canadian breweries, the ratio can be as high as 20:1 and more in inefficient operations and in regions with plentiful and cheap water supply (e.g., Montréal, St. John's); it can be less than 4.5:1 in breweries that have invested in an efficient water-use system. Such systems involve, apart from the usual conservation measures, multiple and ingenious ways of reusing water in areas where product quality is not impaired. Some progressive breweries (Japan, the United States) have achieved ratios better than 3:1.

Reducing water consumption in a brewery can be profitable and, as water is tangible, conservation can normally be accomplished more easily than direct energy-saving activities.

Breweries usually pay for water twice: in purchase costs and in sewer charges (the latter being apart from possible effluent surcharges). It makes sense to save these costs through conservation measures. However, the use of water in a brewery has a strong energy consumption connotation. For example, a large brewery with two million hectolitres per year output and a water-to-beer ratio of 9:1 had an incoming water average temperature of 9°C, but the combined effluent temperature averaged 28°C. As the temperature measurements of individual waste streams indicated, most of the warm wastewater originated in the packaging department. The annual energy losses in just the heat content were staggering. Energy-saving opportunities were subsequently identified in the area.)

The direct relationship between high specific water usage and specific energy consumption has been shown time and time again.

Among the other reasons for water conservation are concern for the environment (e.g., overuse of a valued resource, excessive wastewater treatment costs, hence energy used) and a desire to demonstrate responsible corporate citizenship.

As with lighting and electricity, good housekeeping practices are the logical start for water conservation efforts and can bring impressive initial gains. Such practices include elimination of leaky taps, the shutting off water hoses and eyewash fountains. In the example of eyewash fountains (unwittingly used by employees as a convenient source of cold potable water), a large brewery with 65 fountains saved almost $45,000 a year by shutting them off. Replacing them with drinking water coolers had a quick return on investment.

The following table illustrates the leaking tap losses:

Amount of Water Lost Due to Leakage

Leakage Rate	Daily Loss	Monthly Loss	Yearly Loss
One drop/second	4 L	129 L	1.6 m^3
Two drops/second	14 L	378 L	4.9 m^3
Drops into stream	91 L	2.6 m^3	31.8 m^3
1.6 mm stream	318 L	9.4 m^3	113.5 m^3
3.2 mm stream	984 L	29.5 m^3	354.0 m^3
4.8 mm stream	1.6 m^3	48.3 m^3	580.0 m^3
6.4 mm (¼") stream	3.5 m^3	105.0 m^3	1260.0 m^3

(Note: 1 imp. gal = 4.546 L; 1 m^3 = 1000 L = 220 imp. gal)

Knowing the local rates, anyone can calculate the unnecessary wastage outlined above. Chances are that there are several leaks

In a brewery with a water-to-beer ratio of 6.5:1, use of water per hectolitre of beer produced was broken down as follows:

- Raw material: 1.3 hL/hL
- Cleaning duties: 2.9 hL/hL
- Heat transfer: 0.7 hL/hL
- Other (including losses) 1.6 hL/hL

Among the processes that consume the most water are:

- bottle and keg washing
- cooling
- tunnel pasteurization
- cleaning-in-place (CIP) and rinsing of process equipment
- mashing and sparging
- high-gravity beer dilution water (particularly for light beers)
- floor washing
- filler vacuum pumps
- line and filler flushing

TIPS:

Low or No Cost (payback period is six months or less):

✓ Review current operating practices. Prepare a mass balance of water use in different areas of the brewery
✓ Instil good housekeeping practices in all employees, maintain awareness and transform the newly acquired knowledge into habit
✓ Do not let water run unnecessarily (taps, hoses, eyewash fountains, drinking fountains, etc.)
✓ 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
✓ Identify all hoses and ensure that the smallest diameter necessary is used. Fit hoses with automatic cut-off valves (guns) where appropriate
✓ Ensure that the water supply for process stops during idle periods (after-filler bottle crown flush, can rinser, last rinses in the bottle washer, etc.)
✓ Repair leaks (valves, hose clamps, etc.)
✓ Insulate/enhance insulation of hot and cold water pipes and holding tanks to reduce cooling load on chillers and heating load on heaters
✓ 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
✓ Check and adjust as necessary the appropriate water heating set points
✓ Segregate the hot water system according to various temperature requirements to reduce unnecessary tampering. Consider setting up a system where discrete hot water boilers feed loads of similar temperature, so that the highest temperature does not dictate all loads
✓ Minimize (particularly hot) water overflow occurrences
✓ Review the bottle washer operation
✓ Ensure that the tunnel pasteurizer operates in a thermally balanced mode
✓ Re-use all rinse water from cleaning operations wherever possible, with due regard to product quality implications. For example:
    - CIP last rinse

- Internal keg washing final rinse
- Bottle washer last rinse for pre-rinse and bottle pre-wetting

✓ Re-use kettle stack deodorizer spray water
✓ Collect uncontaminated cooling water for re-use

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

✓ Install closed-loop cooling water systems (cooling towers) to eliminate once-through cooling water (double costs on water and sewerage)
✓ Consider replacing old hot water boilers with high-efficiency units (about 95% with condensing heat recovery)
✓ Install adequate holding tanks to suit the requirements of a water re-use system. Consider using old, unused tankage from the brewery or buying second-hand stainless or new reinforced plastic (RFP) tanks
✓ Install delayed closing/timed flow taps on wash basins in the restrooms

Capital Cost (new equipment required; payback 3 years or more):

✓ 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, correct deficiencies, and set progressively tighter consumption targets
✓ Make the water management a part of computer-monitored and controlled system of overall brewery utilities management
✓ Install water recuperation and re-use systems throughout the brewery

2.10 WASTEWATER

Regardless of how effectively a brewer controls water usage, copious quantities of wastewater are discharged. 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 a 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. For that reason municipal treatment plants welcome it. Municipal treasurers welcome it, too, as it often offers a chance to collect significant surcharges because of high BOD_5 loading for the treatment plant. (Typical range is 1,000 to 2,500 mg/L BOD_5.) Costs associated with wastewater may include, depending on the location, the following charges:

- 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, increasingly municipalities prohibit pH outside of 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. Recently, municipalities faced with rising costs for sewer system upkeep are showing little tolerance for pH transgressions and are forcing industries to comply with their by-laws. A large, multi-plant company recently installed pH-adjustment systems in all its breweries.

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, spilled spent yeast or spent grains during loading for transport and spilled beer from road tankers. For a brewery, storm sewer contamination can pose serious, costly difficulties with a number of authorities. Procedures must be implemented to prevent storm sewer contamination.

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

- the "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
- the cost of using pH-adjusting materials

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

Improvements in product-in-process management will minimize in-brewery beer losses, typically 2% to 5% of total beer production and even more. 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 labelling, quality defects), exploding bottles in the pasteurizer, beer frozen in transportation, and returned beer from the trade.

A brewery with its own wastewater treatment plant (WWTP) (and there are currently two breweries in Canada with one) uses a huge amount of electricity. Elsewhere, energy savings are related to the reduction of effluent volume and to the pH adjustment rather than to the BOD_5 loading and are relatively minor.

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. Certain brewery streams have, in rough figures, the following BOD_5:

• Dense liquid spent yeast:	160,000 mg/L BOD_5
• High gravity beer:	over 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

TIPS:

Low or No Cost (payback period is six months or less):

✓ Remove hot wort trubs with the minimum amount of high-pressure water, and dispose of them 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

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

✓ 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 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 (new equipment required; payback 3 years or more):

✓ Install/convert the pH-adjusting station to use CO_2 or flue gas
✓ 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, and review the efficiency of electric motors and drives as appropriate

2.11 REWORK, REJECTS AND SCRAP

Waste is everything above the *absolute* minimum of raw materials, supplies, energy and work that must go into making a product.

Reworked, rejects 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 9001/2 international standard principles dealing with quality management systems and the ISO 14 001 environmental management standard, will minimize occurrences of product-in-process being reworked or rejected and finished product being scrapped. Omitting the negative product quality implications, some examples of energy waste involved in these employee-demoralizing occurrences (symptom and commonly applied solution) are:

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
- wasted energy in pumping, heating and cooling of large volumes of water and beer (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 analyse 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.

TIPS:

Low or No Cost (payback period is six months or less):

✓ Implement a management system with designations of responsibility and accountability, to routinely monitor 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 (retrofit of equipment or buildings required; payback period is 3 years or less):

✓ Implement a quality management system (along ISO 9001/2 standard) and an environmental management system (along ISO 14001 standard) alone or in combination to ensure quality production and due care of environmental issues

2.12 By-Products Processing

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.

TIPS:

Low or No Cost (payback period is six months or less):

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

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

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

Capital Cost (new equipment required; payback 3 years or more):

- ✓ 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

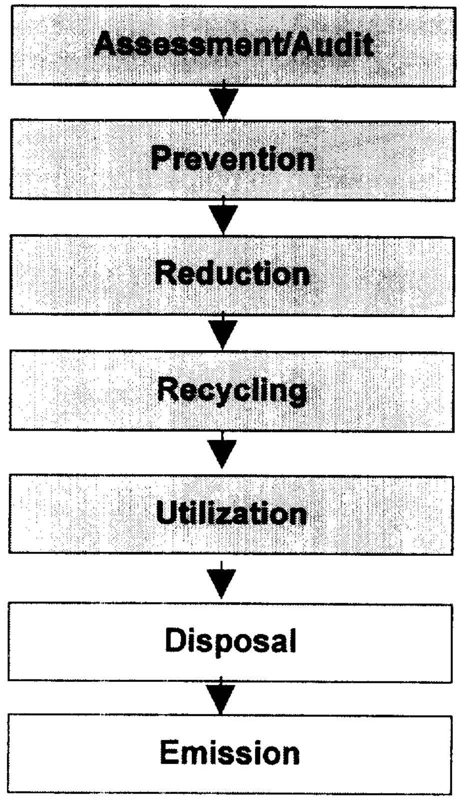
2.13 SOLID WASTE

In Canadian society today, indiscriminant waste disposal is no longer acceptable. Waste must be reduced - with emphasis on avoidance, reuse and recycling. Solid waste disposal should occur only as a last resort.

Most of the energy input into what has become solid waste in a brewery occurred outside the brewery. Yet even solid waste presents an opportunity for energy efficiency, chiefly related to the generation of unnecessary waste (misuse of process resources), collection and storage of solid waste (fuel or electricity for transport and storage space heating, if indoors), and to its disposal (fuel for transport).

A brewery should minimize both the mass and volume of solid waste going to landfill because it makes economic and environmental sense. The waste management strategy in a brewery should entail evaluation of the steps described in the following flowchart, and their application to each of the brewery's waste steams. This will reduce the number of instances where the last-resort steps, either disposal or emission, happen:

Waste Management Strategy



Typically, a disposal company charges the brewery for dumpster pickup and for the mass (weight) charges that the landfill site assesses. The monetary gain from reduction is easy to quantify and project on an annual basis.

Solid waste management, expressed as the "three Rs": Reduce, Re-use, Recycle, can reduce the amount of solid waste sent to the landfill. Segregate waste streams into:

- re-useable components
  - work gloves
  - aprons, synthetic-fibre coveralls
  - salvageable maintenance parts

- saleable components
  - uncontaminated broken glass (cullet)
  - polyester pallet strapping
  - crown boxes
  - bulk or shredded cardboard (other than baled boxes from returned empties)
  - steel, stainless steel, copper and brass scrap
  - aluminum from shredded cans

- general garbage

Waste streams that cannot be sold may be disposed of at no cost rather than taken to the landfill (see "Tips" below).

Solid waste normally hauled off to landfill contains at least 50% air voidage. A solid waste compactor helps to reduce voidage to about 10%, providing a corresponding 40% reduction in waste volume and associated disposal costs.

Reducing the mass and volume of garbage going to landfill will result in further savings from having to rent fewer dumpsters from the disposal company. Resulting disposal costs may be only a fraction of what they used to be before the start of the management program.

TIPS:

Low or No Cost (payback period is six months or less):

- ✓ Conduct a comprehensive solid waste audit in the entire brewery (have the disposal company conduct the audit); analyse the results; draw and implement conclusions
- ✓ Review the current disposal contract; evaluate it competitively
- ✓ Organize a team of volunteers or otherwise implement a solid waste management program along the "three Rs"
- ✓ Investigate markets for saleable streams of solid waste
- ✓ Evaluate a wash program for used work gloves and other salvageable pieces of protective clothing that are normally discarded
- ✓ Give away broken, unrepairable wooden pallets to employees for firewood
- ✓ Give away unsold crown boxes
- ✓ Give away contaminated cullet to a road construction company to be used in the roadbed foundation layer
- ✓ Give away or contract for the disposal of kitchen waste and compostable waste

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

- ✓ Install designated containers throughout the brewery to collect separate waste streams

Capital Cost (new equipment required; payback 3 years or more):

- ✓ Install a waste compactor

2.14 HEATING, VENTILATING AND AIR CONDITIONING

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.

⇨ TIPS:

Low or No Cost (payback period is six months or less):

- ✓ 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
- ✓ Lower the heating temperature in storage areas to as low as possible
- ✓ Install setback timers on thermostats controlling space heating during non-working hours. Prevent tampering with the thermostat setting by unauthorized employees
- ✓ Use de-stratification ceiling fans in areas with high ceilings
- ✓ Ensure that outside doors are closed
- ✓ Shut down exhaust or supply fans during non-working hours
- ✓ 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
- ✓ Fit blinds or heat-deflecting film on sun-exposed windows
- ✓ Clean/exchange intake air filters regularly

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

- ✓ Install infrared heating for large open areas (replace steam or hot water heating radiators) to heat people rather than space
- ✓ Minimize unwanted infiltration of outside air into the brewery (reseal cracks, repair or replace doors, link loading bay doors opening to the activity, etc.)

Capital Cost (new equipment required; payback 3 years or more):

- ✓ Review the adequacy of the building envelope's thermal insulation, particularly roofs, and correct if required
- ✓ Use reflective insulation, or paint flat roofs white over refrigerated areas
- ✓ Evaluate the application of recently developed regenerative rooftop heat recovery ventilation systems

2.15 LIGHTING

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.

TIPS:

Low or No Cost (payback period is six months or less):

- ✓ Educate employees about good housekeeping practices; encourage change of wasteful habits; encourage employees to shut off lights when not required
- ✓ 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
- ✓ Institute a regular lamp-cleaning program that will maintain lumen output and reduce total lighting requirements. 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
- ✓ Use a programmable or photocell-governed system for general exterior lighting. Reduce its level to the minimum safe level. Install motion detector switches on exterior security lighting

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

- ✓ Replace all standard fluorescent tubes with high-efficiency tubes
- ✓ 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
- ✓ Replace old ballasts with an energy-efficient type (especially important if power factor is low and the brewery pays penalties as a consequence)
- ✓ Reduce the level of general lighting to a minimum and provide task lighting at workstations, as required

2.16 Some Brewery Process-Specific Energy Efficiency Opportunities

Other energy efficiency opportunities are available in addition to what has been addressed in this guide. With due consideration given to product quality, brewery management may find it worthwhile to consider the following

Brewing:

- Processing beer at high gravity throughout all major energy-using activities will reduce overall specific energy consumption. In addition, the brewery will realize a de facto increase of production capacity (better utilization of process vessels and equipment)

- Gradual operation of steam valves on the kettle will modulate demand on the boiler. Control of steam use in wort boiling (programmable-logic controllers [PLC], personal computer [PC] applications) using steam mass flow control will prevent energy wastage.

- Verification of the evaporation rate may reveal that evaporation is well in excess of the adequate minimum (generally set by brewing researchers at between 6% to 8%) wasting energy and water.

- Volume-based rather than time-based control on burst rinses and CIP flows will reduce the volume of water used.

- Reduction in boiling time (while still achieving the required evaporation rate) will give a corresponding decrease in energy use.

- Recovery of high-grade heat from kettle vapours, using either spray condensers or heat exchangers (spiral or plate), has significant energy conservation potential. However, hot water balance in the brewery must be carried out beforehand to determine best uses for recovered hot water. With the aid of PC or PLC, it is possible to obtain optimum recovery of the highest-grade heat possible and storage utilization. Benefits include energy savings, savings in water use and cost, and effluent cost savings. Heat recovery in the brewhouse is often a key to more effective energy use in the entire brewery.

- Recovered heat from the kettle can be used for hot water preparation, as well as for preheating of wort before boiling or with steam ejector or mechanical compressor for wort boiling.

- The brewery hot water system should be optimally based on recovered heat utilization rather than on heating cold water with steam or electricity. To optimize it, hot water balance should be calculated for the whole brewery. Using heat-recovered hot water for functions such as CIP, bottle washing, and sterilization should be investigated. Hot water storage tank capacities should be calculated carefully to avoid hot water overflows and sewering.

- Keeping refrigerated areas as dry as possible (avoiding hosing down surfaces) will significantly reduce the refrigeration load.
- Optimizing CIP, the reduction and re-use of rinse water and a reduction in temperature of cleaning solutions will bring about energy and water savings.
- Use of a low-pressure blower instead of high-pressure compressed air for conveying spent grains may be more economical.

Packaging:

- Insulate to economic thickness bottle washers and tunnel pasteurizers and steam and water pipes, valves, traps and the condensate system associated with their operation. Major savings in steam and water consumption will ensue, with reduced requirements on the HVAC load in the packaging hall and an improvement in the work environment.
- The (multiple) regenerative water circulation system in a pasteurizer requires optimum balancing. Consider using a cooling tower for cooling water conditioning to bring additional energy and water savings.
- Direct steam injection for heating water in pasteurizers and soakers results in loss of condensate.
- Heat from bottle washers and the bottle/can pasteurizer can be recovered.
- Water from soakers and pasteurizers can be recycled.
- Water from the filler vacuum pumps and cooling water from the baler hydraulic pumps can be recycled.
- Review brewery-specific pasteurization requirements to achieve safe minimum pasteurization units (P.U.). The review may result in a reduction of an unnecessarily high P.U. and in energy savings.
- Installation of a heat recovery system from keg washer will save 40% of keg cleaning energy and recover 85% of heat required for heating incoming water.
- Use of low-pressure blowers, instead of air compressors, would enable tank pressurization during emptying without the use of CO_2 and without disturbing the protective blanket of CO_2 atop the beer.

- Optimize the rinsing section in the bottle washer; check the sizing and positioning of the nozzles; and tie the rinsing section function to the actual washer operation to avoid wasting water.

- Optimize packaging operations to achieve the best line efficiency possible. Line efficiency affects energy consumption to a great extent. Inefficient production results in higher specific energy consumption due to losses when the line is idle. Additionally, increased efficiency can result in a lesser number of shifts required to package the same volume of beer.

- Conveyors running without a load waste electrical energy, lubricants and water; contribute to accelerated wear and tear; and increase the power demand.

- Avoid using water hoses instead of brooms in areas where a broom and shovel will do a perfectly good job (e.g., on spilled solids such as spent grains; and on broken glass around fillers).

2.17 OTHER ASPECTS OF ENERGY EFFICIENCY IN A BREWERY

Maintenance:

Proper and timely maintenance has a profound effect on efficient operations in a brewery. Large quantities of energy, water and other utilities can be wasted, and lower plant productivity can result from lack of maintenance.

Ensure that any installed meter has a provision for telemetry, required in setting up an effective energy and utilities management system.

Synthetic lubricants retain a relatively constant viscosity over an extended temperature range. They lubricate better, resist oxidation better and last longer than petroleum-based lubricants. Experience has shown that savings of 10% to 20% of the energy normally lost in the operation of electric motors, gearboxes, etc. can be realized when synthetic lubricants are used. These benefits, together with less frequent oil changes and resultant material and labour savings, make synthetic lubricants the preferred choice for many breweries, particularly on air compressors and large electric motors. The advice of manufacturers and/or an expert on proper lubrication selection should be sought first. It is important to ensure compatibility of the synthetic lubricant in question with the particular refrigerant used, seals in the machine, etc.

Electric motors:

Often a larger motor is used than is necessary for average power use. Size is often dictated by the motor's ability to handle the peak load, increases in production and safety factor against failure in critical processes. However, the practice of using oversized motors causes them to run under loaded. A motor should run in the 75% to 100% load range. When operated below 75% load, efficiency drops off considerably. Such a decrease may cause the overall brewery power factor to drop below the penalty-free minimum (e.g., 90%).

The minimum efficiency of high-efficiency (HE) motors starts at 80% for a one-horsepower motor and steadily increases to 93% for a 100 HP motor and to 95% for a 500 HP motor.

A brewery should have a policy of replacing old motors when needed with new, better built and more efficient HE motors.

Using new technology such as linear motors and AC solid state variable frequency drives, and timing belts and flat belts instead of V-belts, provides further energy efficiencies.

The work done at Suntory Co.'s Masushino brewery in Japan, published by CADDET, demonstrated the efficiencies that can be achieved from installing variable speed-variable frequency inverters for induction motors. This equipment is used for pumping and other applications.

2.18 Energy Efficiency Potential of New Brewery Process Technologies

Following is a brief listing of recent and new technologies and ideas available to a brewery.

Expert computer control systems:

An expert computer system uses specialist knowledge, usually obtained from a human expert, to perform 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 and reducing delivery times
- improving the quality of advice and analyses to enhance both operating efficiency and product quality

- making rare expertise readily available, thereby alleviating skill shortages. This should be considered before valued, experienced professionals retire from the brewery.

These expert computer 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:

Individual programmable logic controllers (PLC) may now be 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™ are available. Their application in such areas as the boilerhouse, refrigeration, and packaging can assist energy saving efforts in the brewery.

Combined heat and electrical power generation:

One Canadian brewing company, Labatt Brewery in London, Ontario, has adopted cogeneration, to take advantage of favourable Hydro policies at the time (1994). With deregulation of the electricity supply in Canada, other breweries may consider making the required large investment.

Mechanical vapour recompression (MVR):

Mechanical vapour recompression (MVR) is a proven, energy-efficient method of brewing that has been employed worldwide. The method regains 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.

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), recovery and 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 North American breweries.

Maximizing draught beer production and bulk distribution by road tankers:

Some regulatory changes relating to beer distribution and sale in Canada would have to be enacted first to allow delivery of beer in bulk to licensed establishments. Bulk-beer distribution is common elsewhere. Breweries producing draught beer (unpasteurized by heating) have the lowest specific energy consumption (as low as 90 MJ/hL) as opposed to the current North American standard of about

260 to 300 MJ/hL.

Moreover, the distribution of beer by (compartmentalized) road tankers directly to large accounts (pubs, restaurants, hotels, arenas, ballparks, etc.) which have installed a corresponding tank system for dispensing, has other obvious economies. One of them is the best possible ratio of beer volume to beer container surface area which minimizes the use of cleaning materials and energy and water consumption.

These features of draught beer production and distribution should not be forgotten in a world of dwindling natural resources and increased demands on energy.

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.

3.0 *IMPLEMENTATION OF ENERGY EFFICIENCY OPPORTUNITIES*

A good energy and water management system is the precursor to energy efficiency improvements. Experience has shown that initial savings in the region of 5% to 15% can be realized by installing an energy and utilities management system. Most of the benefit usually comes from monitoring (i.e., metering) consumption and from good housekeeping practices, without modification to process equipment. A body of literature has been written about energy management and energy efficiency improvement approaches, e.g., *Learning from Experiences with Energy Management in Industry,* by CADDET).

The advantages of reducing energy and utilities consumption include:

- profit improvement
- reduced environmental impact (losses, effluent, emissions, solid waste)
- improved work environment for employees
- green image – the brewery can legitimately present itself to the community as a protector of the environment

In setting up an energy efficiency improvement program, it is assumed that the energy policy has been prepared and adopted with the demonstrated support of top management. The organizational infrastructure has been put in place and includes:

- A competent person in charge.
- A team of volunteers from various departments.
- Sufficient support provided by management (allowance for meetings, research of issues, data gathering, availability of records and data, budget, support from other departments, etc.).
- An agreement on how the team will govern itself (e.g., rotating chairmanship, recording of minutes, conflict resolution, frequency of meetings, organization of work).
- Defined terms of reference (objectives, scope, jurisdiction, timelines, reporting frequency).

In practical terms, the start of an energy efficiency improvement program will consist of essentially three steps: quantifying unit costs for energy and utilities; developing a list of major energy consuming equipment; identifying and quantifying savings opportunities in the brewery processes.

Subsequent work may be structured in the following way:

1) Establish the baseline – conduct an energy/utilities audit

2) Plan the attack:
   - Purpose
   - Accuracy requirements
   - Measuring and metering equipment (fixed and portable)
   - Establishing material balances (steam, water, CO_2, etc.)
   - Identify other process calculations needed
   - Documenting and calculating tools
   - Assigning audit team members and others with specialized knowledge and skills
   - Establishing person-hours and schedule duration
   - Collecting, analysing and documenting results of data
   - Reviewing/developing specific consumption statistics
   - Benchmarking against industry leaders

3) Identify and select the projects:
   - Gathering of ideas
   - Grouping of project by type (related to electricity, heat, compressed air, refrigeration, etc.)
   - Focusing on best-return or most urgent projects (evaluate them objectively; for example use Pareto analysis and quantify)
   - Developing action plan

4) Realize the project

5) Verify result

6) Communicate results to management and all employees

7) Celebrate success

8) Review, confirm or correct newly established processes/ practices

9) Start the cycle anew

As someone said: "Crawl before you walk. Walk before you run."

Do not run the risk of failure at the beginning of the program! To build up the team's confidence and enthusiasm, start small and select easily realizable, short, simple projects with a tangible, high-visibility impact before trying to solve more complex issues.

Highlight the role of the team. Spread the word. Educate and involve others in the work. Make everyone feel they have ownership in the program. Celebrate success – it is contagious!

4.0 *INTEGRATION OF ENERGY AND UTILITIES MANAGEMENT WITH OTHER MANAGEMENT SYSTEMS*

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. A generic blueprint for implementation of an energy efficiency opportunities program was discussed in Section 3.0.

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. Such morale-depressing sentiments need not arise if a program (such as energy efficiency improvement) is made an integral part of the overall improvement strategy. An energy efficiency improvement program can profit from synergies with other programs being contemplated or already in place. Some of those may be:

- Hazard Analysis Critical Control Points (HACCP)
- Quality Management System (QMS) ISO 9001/2 international standard
- Environmental Management System (EMS) ISO 14001 international standard
- Total Quality Management (TQM)
- Continual Improvement (CI)

All of these programs have something in common – the desire to improve quality in the broadest sense of the word. Their systematic, structured, thought-out approach makes them valuable. Thousands of books and articles have been written about the systems. Following is a brief outline.

4.1 HACCP (Hazard Analysis Critical Control Point)

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.

Courage Brewery (U.K.) uses 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. As with any high-performing system, HACCP requires thorough documentation and communication. It is a further step towards Total Quality Management (TQM) – another rung up the ladder.

HACCP improves plant operations and gives greater equipment efficiencies with improved microbiological quality.

HACCP works with ISO 9001/2 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 is presently developing a generic HACCP program for brewers.

4.2 ISO 9001/2

In the ten years since its introduction in 1987, an estimated 200,000 or more organizations in the world have become registered to one of the ISO 9000 series of standards. As of spring 1998, there are almost 5,000 ISO-registered companies in Canada and a further 17,000 in the United States. The registration process is based on a rigorous audit and serves to certify that an organization has successfully implemented a quality management system based on the ISO 9001/2 standard. There are currently 16 Registrars operating in Canada.

ISO 9001/2 reflects, just as ISO 14001 does, the four commandments of the famous quality guru, Dr. Deming: "Plan – Do – Check – Act", in a spiral of Continual Improvement. The quantifiable benefits of ISO application in the development of a good quality system 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
- improved market share

4.3 ISO 14001

The implementation of an environmental management system (EMS) as specified by the ISO 14001 standard 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 EMS should enable the organization to:

- establish an environmental policy appropriate to the organization
- identify environmental aspects arising from the past, present or planned activities, products or services, and determine the environmental impacts of significance
- identify relevant legislative and regulatory requirements
- identify priorities and set appropriate environmental objectives and targets
- establish structure and programs to implement a policy to achieve the objectives and targets
- facilitate planning, control, monitoring, corrective action, auditing and review activities to ensure both compliance with policy and that the EMS remains appropriate
- be capable of adapting to changing circumstances

All these criteria are also suitable to an energy efficiency improvement effort.

The authors suggest that if an organization is not thinking of installing EMS, it should ask itself these questions:

1) Am I satisfied that my current EMS, assuming I have one, gives me a "due diligence" defence should my company contravene an environmental law?

2) Do I know the cost to my "bottom line" of my company's environmental impact – scrap, rework, air and water effluent and solid waste?

3) Are my customers, including export customers, likely to demand that I show evidence that my company has an EMS in place or that my company supplies environmentally friendly products?

4) As well:

   a) Will an EMS, like ISO 14001, give my company a marketing edge?
   b) Will my bank and/or insurance company give preference if my company has an EMS in place or penalize it if it does not?
   c) Will an effective EMS system improve my company's profit?

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 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

Recognizing these benefits, a growing number of companies are opting for an integrated approach.

5.0 APPENDICES

5.1 GLOSSARY OF TERMS

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.
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.

Economizer	A heat exchanger that recovers energy from flue gas.
Emission	Pollution at the point of discharge.
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.
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	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.
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.

Peak demand	The maximum demand on electric power that occurs in a timed period, e.g., 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 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.
Saturated steam (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.
Superheated steam	Steam at a temperature higher than the saturation temperature.
SS – suspended solids	Solids that can be separated by filtration through a membrane

5.2 ENERGY UNITS AND CONVERSION FACTORS

Basic SI Units	
Length	metre (**m**)
Mass	gram (**g**)
Time	second (**s**)
Temperature	Kelvin (**K**)

Multiples		**Fractions**	
10^1	deca (**da**)	10^{-1}	deci (**d**)
10^2	hecto (**h**)	10^{-2}	centi (**c**)
10^3	kilo (**k**)	10^{-3}	milli (**m**)
10^6	mega (**M**)	10^{-6}	micro (**μ**)
10^9	giga (**G**)	10^{-9}	nano (**n**)
10^{12}	tera (**T**)		
10^{15}	peta (**P**)		

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^{2}K
	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)

Conversion factors		
Multiply	**By**	**To Obtain**
Volume:		
L	0.219975	gallons (Imperial)
L	0.264179	gallons (US beer)
L	0.0088	Barrels (Canadian beer)
L	0.0085	barrels (US beer)
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 °F
Heat flow rate:		
W	3.412	Btu/h
U value, heat transfer coefficient:		
W/m^2K	0.1761	Btu/ft^2 h °F
Conductivity:		
W/m K	6.933	Btu in/ft^2 h °F
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		
Unit	**Equals**	**or Equals**
1 Therm	100,000 Btu	29.31 kWh
1 ft^3 of natural gas	1,000 Btu	0.2931 kWh
1 US gal #2 oil	140,000 Btu	41.03 kWh
1 Imp. gal #2 oil	168,130 Btu	49.27 kWh
1 US gal #4 oil	144,000 Btu	42.20 kWh
1 Imp. gal #4 oil	172,930 Btu	50.68 kWh
1 US gal #6 oil	152,000 Btu	44.55 kWh
1 Imp. gal #6 oil	182,540 Btu	53.50 kWh
1 boiler horsepower	33,480 Btu/h	9.812 kW
1 mechanical horsepower	2,545 Btu/h	0.7459 kW
1 ton refrigeration	12,000 Btu	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	

In Canada, the value of 1 Btu (60.5 °F) = 1.054615 kJ was adopted for use in the gas and petroleum industry. ISO recognizes the value of 1.0545 kJ.

Commonly used temperature units: Celsius (**C**), Fahrenheit (**F**)

0°C = 273.15°K = 32°F   1°F = 5/9 °C   1°C = 1°K

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.

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Maunder Britnell Inc. 1993 report on energy efficiency R&D opportunities in the food and beverage sector for Natural Resources Canada (# EA9710-8-1).

Product knowledge reference guides on: Power quality; Adjustable speed drives; Motors; Membrane technology; Pumps; Refrigeration; etc., monothematic brochures and guides from Ontario Hydro.

Guides to energy management, BC Hydro.

International case studies related to food and beverage industries, prepared by the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), 1994, for example report on:

R028 Heat recovery from vapours
R149 Refrigeration heat recovery system
R077 Hot stand-by for a steam boiler
R135 An ice pond system for industrial process cooling
R029 Heat recovery from exhaust air
R045 Combined heat and power from stand-by generators
R048 Energy saving with heat recovery systems
R125 Steam-condensate closed system
R183 High-efficiency motors for fans and pumps
R014 Energy utilization in wastewater treatment plants
R016 Heat pump using sewage water as heat source

Reducing energy cost by steam metering, Good Practice Guide No. 18, Energy Efficiency Office, Department of the Environment, U.K., 1991.

Energy efficient operation of industrial boiler plant, Good Practice Guide No. 30, Energy Efficiency Office, Department of the Environment, U.K., 1992.

Guide to the selection & installation of compressed air services, British Compressed Air Society, 1992.

ISO standards:

- ISO 1217:1986 Displacement compressors acceptance tests
- ISO 5388:1981 Stationary air compressors safety rules and code of practice
- ISO 7183:1986 Compressed air driers specification and testing
- ISO 4126:1981 Safety valves general requirements
- ISO 8573-1:1991 Compressed air for general use. Part 1 Contaminant and quality classes

Conservation of water and reduction of effluent; The Joint User/Maker Committee, The Institute of Brewing, U.K., 1989.

Water conservation and economy, Technical Circular No. 187, The Brewers' Society, U.K., 1990.

Brauwelt Brevier (in German), annually issued handbooks of current good brewing practices, Carl Hans Verlag, Nürnberg, Germany.

Internet locations – some useful addresses:

- Natural Resources Canada, Canada's Energy Efficiency Home Page: http://oee.nrcan.gc.ca

- Gas Technology Canada: www.gtc.ca
- Climate Change Voluntary Challenge and Registry Program: www.vcr-mvr.ca
- Netherlands Energy Research Foundation (ECN): www.ecn.nl/eii/main.html
- Canadian Committee on Electrotechnologies: www.cce.qc.ca
- Brewing literature publishing house (in English, German) Carl Hans Verlag, Nürnberg, Germany: redaktion@brauwelt.de
- Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET): www.caddet-ee.org
- Office of Industrial Productivity and Energy Assessment (U.S.): oipea-www.rutger.edu
- Institute of Brewing, London, U.K., publishers of *Ferment* and *Journal of Institute of Brewing* : enquiries@iob.org.uk

Brewing journals:

- Brauwelt (in German), Verlag Hans Carl, Postfach 990153, 90411 Nürnberg, Germany.
- The Brewer, Brewers Guild Publications Ltd. 8 Ely Place, Holborn, London, EC1N 6SD, U.K.
- Brewers Guardian, Hampton Publishing Ltd., 97 Station Road, Hampton, Middlesex TW12 2BD, U.K.
- Brewing and Distilling International, 52 Glenhouse Road, Eltham, London SE9 1JQ, U.K.
- Technical Quarterly MBAA, 211 21N Mayfair Road, Suite 310, Wauwatosa, Wisconsin 53226, USA.
- Ferment, The Institute of Brewing, 33 Clarges Street, London, W1Y 8EE, U.K.
- Brewers Digest, Siebel Institute of Technology, 4049 W. Peterson Ave., Chicago, Illinois 60646, USA.
- The New Brewer – The Magazine for Micro- and Pubbrewers, The Institute for Brewing Studies, Boulder, Colorado 80306-1679, USA.

5.4 CANADIAN FEDERAL "ON-SITE/À LA SOURCE" PROFESSIONAL EMPLOYMENT ASSISTANCE PROGRAM

The most commonly mentioned obstacle to implementating process improvements in an industry is lack of financial and human resources. The brewing sector is no exception. The Canadian federal government's ON-SITE/À LA SOURCE program, sponsored by the Alliance of Manufacturers and Exporters of Canada, is an industry-government partnership that:

- provides job experience to unemployed professionals
- helps employers address the key environmental, energy and quality management challenges of the 1990s

ON-SITE provides low-cost assistance to organizations that require help with technical projects and that otherwise would not be able to hire someone to do the work. The ON-SITE program places qualified, unemployed professionals "on-site" to help with projects in areas such as:

- Reduction of solid waste
- Reduction and management of solid waste
- Energy management
- Occupational health and safety
- Quality and environmental management

ON-SITE places professionals "on-staff" but not "on-salary". While working, they continue to draw unemployment insurance benefits and have access to training and technical support. At the end of an employee's ON-SITE term, which is usually six months, the employer has the option, but no obligation, to hire the individual. Participating employers are requested to contribute up to $100 per week of their ON-SITE worker's term to defray the cost of program which is borne by the sponsor and the Unemployment Insurance Section 25 Job Creation Program.

The ON-SITE program is a "win-win" solution:

- Employees contribute their expertise and help project implementation while gaining new knowledge in a salary-free fashion.

- Employers get the job done at minimal expense and with no need to add to staffing levels, glean useful information and knowledge from the professionals and have a risk-free chance to evaluate their work should they want to hire the persons eventually.

Interested breweries should call in the nearest ON-SITE/À LA SOURCE office.

5.5 USEFUL CONTACTS

Electric Utilities

Alberta Power Limited
Market Development
P.O. Box 2426
Edmonton, AB T5J 2V6
Tel: (403) 420-7644

British Columbia Hydro
Energy Management Division
1177 Hornby Street, Suite 900
Vancouver, BC V6Z 2E9
Tel: (604) 663-3286

Edmonton Power
Customer Services
Century Place
9803 – 102A Avenue
Edmonton, AB T5J 3A3
Tel: (403) 448-3020

Hydro-Québec
Efficacité Énergétique
1010, Ste. Catherine Ouest
C.P. 6162
Montréal, QC H3C 4S7
Tel: (514) 392-8164

Manitoba Hydro
Energy Management
P.O. Box 815
Winnipeg, MB R3C 2P4
Tel: (204) 474-3341

Maritime Electric Co. Ltd.
Customer Services
P.O. Box 1328
Charlottetown, PE C1A 7N2
Tel: (902) 566-1599

Newfoundland Power
Energy Management
P.O. Box 8910
St. John's, NF A1B 3P6
Tel: (709) 737-2854

Nova Scotia Power
Corporate Programs
P.O. Box 910
Halifax, NS B3J 2W5
Tel: (902) 428-6455

Ontario Hydro
Energy Services and Environment
700 University Avenue (H19-A20)
Toronto, ON M5G 1X6
Tel: (416) 592-3321

SaskPower
Energy Management Services
2025 Victoria Avenue
Regina, SK S4P 0S1
Tel: (306) 566-2914

TransAlta Utilities
Energy Efficiency Programs
P.O. Box 1900
Calgary, AB T2P 2M1
Tel: (403) 267-7345

West Kootenay Power
PowerSmart
1260 Commercial Way
Trail, BC V2A 3H5
Tel: (604) 493-3818

New Brunswick Power
Conservation and Energy Management
P.O. Box 2000
Fredericton, NB E3B 4X1
Tel: (506) 458-3196

Newfoundland and Labrador Hydro
Economic Analysis
P.O. Box 12400
St. John's, NF A1B 4K7
Tel: (709) 737-1354

Winnipeg Hydro
Customer Services
223 James Avenue
Winnipeg, MB R3B 3L1
Tel: (204) 986-2214

Natural Gas Utilities

BC Gas Utility Inc.
Senior Product Engineer, Industrial
1111 West Georgia, 6th Floor
Vancouver, BC V6E 4M4
Tel: (604) 443-6772

Canadian Western Natural Gas
Industrial Marketing
909 – 11 Avenue South West
Calgary, AB T2R 1L8
Tel: (403) 245-7740

Centra Gas Ontario Inc.
Senior Engineer
200 Yorkland Boulevard
North York, ON M2J 5C6
Tel: (416) 496-5221

Centra Gas Manitoba
Senior Engineer
510 444 St. Mary Avenue
Winnipeg, MB R3C 3T7
Tel: (204) 934-3227

Gaz Metropolitan Inc.
Director of Development and Technology Assistance
1717 Du Havre Street
Montréal, QC H2K 2X3
Tel: (514) 598-3461

SaskEnergy
Manager, Energy Management
1945 Hamilton Street, 11th Floor
Regina, SK S4P 2C7
Tel: (304) 777-9368

The Consumers' Gas Company Ltd.
Director Industrial/Commercial Marketing
2235 Sheppard Avenue East, 10th Floor
North York, ON M2J 5B5
Tel: (416) 496-5315

Union Gas Ltd.
Director of Development and Technology
50 Kiel Drive North
Chatham, ON N7M 5M1
Tel: (519) 436-4671

Government and Other

Natural Resources Canada
Industrial, Commercial and Institutional Programs Division
Office of Energy Efficiency
580 Booth Street, 18th Floor
Ottawa, ON K1A 0E4
Tel: (613) 995-3065

Canadian Industry Program for Energy Conservation (CIPEC)
Secretariat
Natural Resources Canada
Office of Energy Efficiency
580 Booth Street, 18th Floor
Ottawa, ON K1A 0E4
Tel: (613) 995-3065

Alberta Department of Energy
Petroleum Plaza,
North Tower, 9945-108th Street
Edmonton, AB T5K 2G6
Fax: (403) 427-7737

British Columbia Ministry of Energy, Mines and Petroleum Resources
Energy Resources Division
617 Government Street, 4th Floor
Victoria, BC V8V 1X4
Tel: (604) 387-5178

Manitoba Department of Energy and Mines
555-330 Graham Avenue
Winnipeg, MB R3C 4E3

New Brunswick Department of Natural resources and Energy
P.O. Box 6000
Fredericton, NB E3B 5H1

Newfoundland Department of Mines and Energy
P.O. Box 8700
St. John's, NF A1B 4J6

Nova Scotia Department of Natural Resources
Founders' Square, 2nd Floor
1701 Hollis Street
P.O. Box 698
Halifax, NS B3J 2T9
Tel: (902) 424-5935

Ontario Ministry of Environment and Energy
135 St. Clair Avenue West
Toronto, ON M4V 1P5
Tel: (416) 323-4321

Prince Edward Island Department of Energy and Forestry
Jones Bldg., 3rd Floor
11 Kent Street,
P.O. Box 2000
Charlottetown, PE C1A 7N8
Tel: (902) 368-4070

Ministère de l'énergie et des ressources du Québec
5770, Quatrième av., Ouest
Charlesbourg, QC G1H 6R1
Tel: (418) 646-5700

Saskatchewan Department of Energy and Mines
1914 Hamilton Street
Regina, SK S4P 4V4
Tel: (306) 787-2526

Brewers and Licensed Retailers Association (formerly The Brewers' Society)
42 Portman Square
London W1H 0BB
United Kingdom
Tel.: 71-486-4831
Fax: 71-935-3991

CSA – Canadian Standards Association
(Authorized distributor of ISO standards, issuer/seller of many industrial and energy-related Canadian standards)
178 Rexdale Blvd.
Toronto, ON M9W 1R3
Tel: (416) 747-4000

Energy Training Ontario
Training Consultant
Seneca College, Newmarket Campus
16775 Yonge Street
Newmarket, ON L3Y 8J4
Tel: (905) 727-8577 or
1-800-572-0712

Energy Efficiency Office
Department of the Environment
Black Horse Road
London SE99 6TT
United Kingdom

ON-SITE / À LA SOURCE
c/o Energy Pathways Inc.
251 Laurier Avenue West, Suite 500
Ottawa, ON K1P 5J6

5.6 Examples of Cost-Saving Measures in Some Brewery Areas

Due to space limitations, only some of the simpler, more common calculations will be shown in the examples below.

Case Study No. 1: 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°C to 29°C, and the compressor oil was at 32°C; it was supposed to operate at 66°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°C, allowing the oil to remain at 66°C. The new flow rate is determined by the formula:

$$NF = \{(29^\circ C - 18^\circ C) : (63^\circ C - 18^\circ C)\} \times OF$$

OF = old flow rate, L/h
NF = new flow rate, L/h

Savings are calculated using the formula:

$$CS = L \times HR \times CF$$

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 No. 2: 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:

$$CS = (HP : \eta) \times LF \times H \times S \times WHP \times CF$$

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 was immediate.

Case Study No. 3: 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:

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

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:

$$CS = P \times L \times HR \times LF \times CF$$

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 and a simple payback of 12 days.

Case Study No. 4: Redirecting air compressor intake to use outside air

A 60 HP air compressor drew air from the engine room where the temperature was 29°C. The annual average outside air temperature was 10.5 °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:

$$WR = (WI - WO) : WI = (TI - TO) : (TI + 460)$$

WR = fractional reduction of compressor work
WI = compressor work with indoor inlet
WO = compressor work with outdoor inlet
TI = annual average indoor temperature, °F
TO = annual average outdoor temperature, °F

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

$$CS = HP \times (1 : \eta) \times LF \times H \times WHP \times CF \times WR$$

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. With the cost of installation (PVC schedule 40 pipe and some rolled fibreglass insulation), the simple payback was 10 months.

Case Study No. 5: 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, generates 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 are completed in the sixth year.

Case Study No. 6: Preheating boiler combustion air with stack waste heat

A 300 HP natural gas boiler was drawing air form the outside that resulted in unnecessary fuel consumption to heat the consumption 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:

$$CS = EC \times (1 - \eta) \times RC$$

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, 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 No. 7: Implementing periodic inspection and adjustment of combustion of a gas-fired boiler

The same 300 HP boiler used as an example in case study no. 6 used excess combustion air that showed as 6.2% oxygen in the flue gas and a temperature of 204°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. With a $750 purchase of a flue gas analyser, the simple payback is 8.2 months.

Case Study No. 8: 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:

$$PS = (HP : \eta) \times LF \times S$$
$$ES = PS \times H$$

PS = anticipated reduction in electric power, kW
ES = anticipated energy savings, kWh/y
HP = total horsepower for the motors using standard V-belts, kW (1 horsepower = .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 power and demand costs cited in case study no. 6, 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 No. 9: 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:

$$PS = HP \times (1 - \eta) \times LF \times S$$
$$ES = PS \times H$$

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 offsets 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 No. 10: 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:

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

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:

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

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.

Case Study No. 11: Turning off equipment 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:

$$ES = \{(HP \times CV) : \eta\} \times HR \times IL$$
$$CS = ES \times EC$$

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

Case Study No. 12: 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°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°C water from the wort cooling. A larger water buffer tank was also installed. The 85°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 No. 13: 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.

Case Study No. 14: 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.

Case Study No. 15: Refrigeration fault diagnosis system

A one million hectolitres 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 (1991 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), analyse faults and recommend preferred actions for establishing the best combination of cooling equipment packages and loads to meet current cooling duty, given the ambient temperatures.

Case Study No. 16: Variable voltage, variable frequency inverters

Variable voltage, variable frequency (VVVF) inverters are well established in induction motor control. A Japanese 2.2 million hectolitres per year 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.

The project also investigated the effects of noise interference on surrounding equipment and carried out measures to alleviate any problems that occurred.

Case Study No. 17: Waste heat recovery

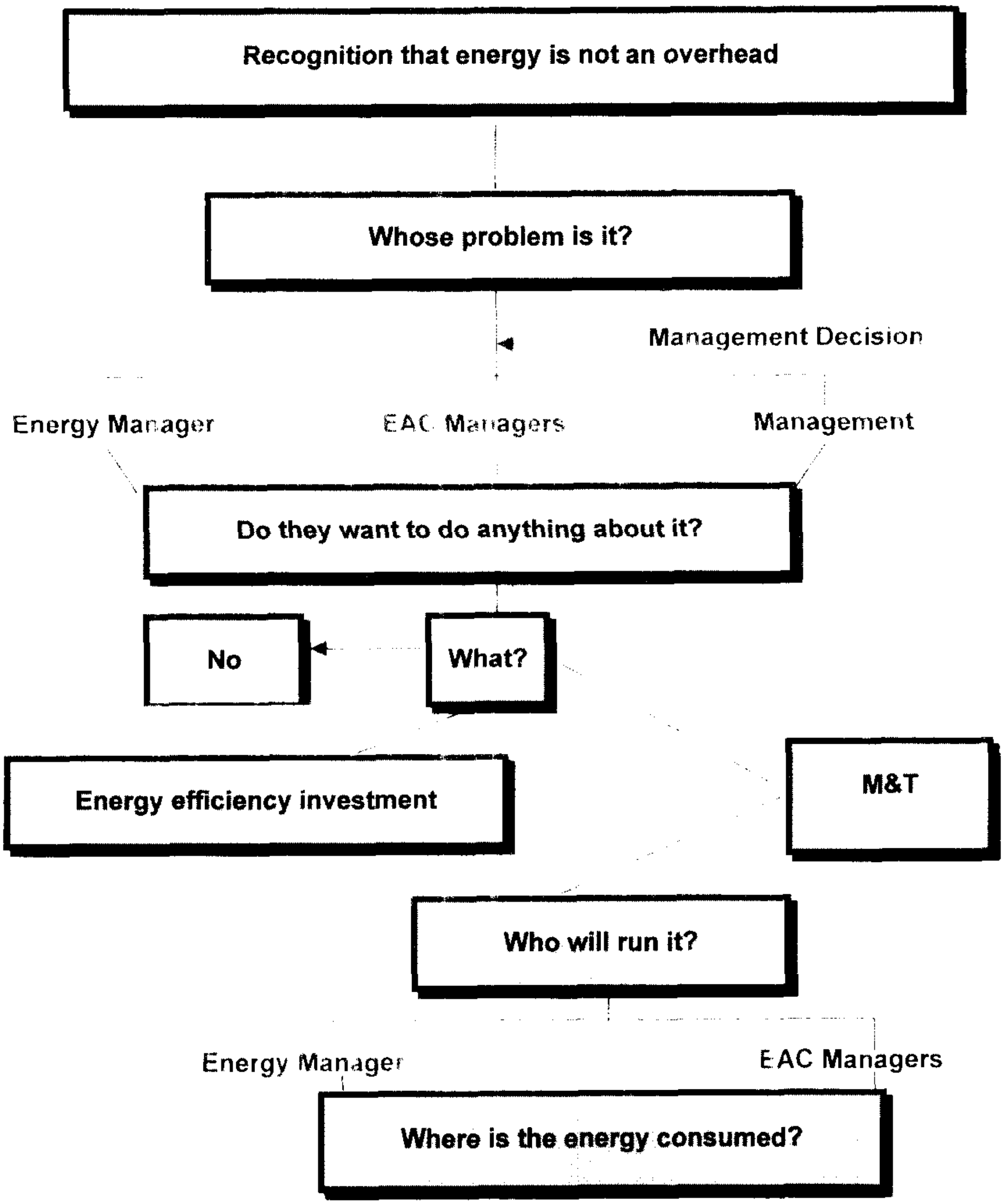
A Canadian Maritime brewery installed a heat pump system to recover hot water for boiler feed and brewing makeup. The system has four major components: an ammonia condenser, a water preheater, the heat pump and water storage tanks.

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 process water, then as a source of energy for a high temperature heat pump. 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.

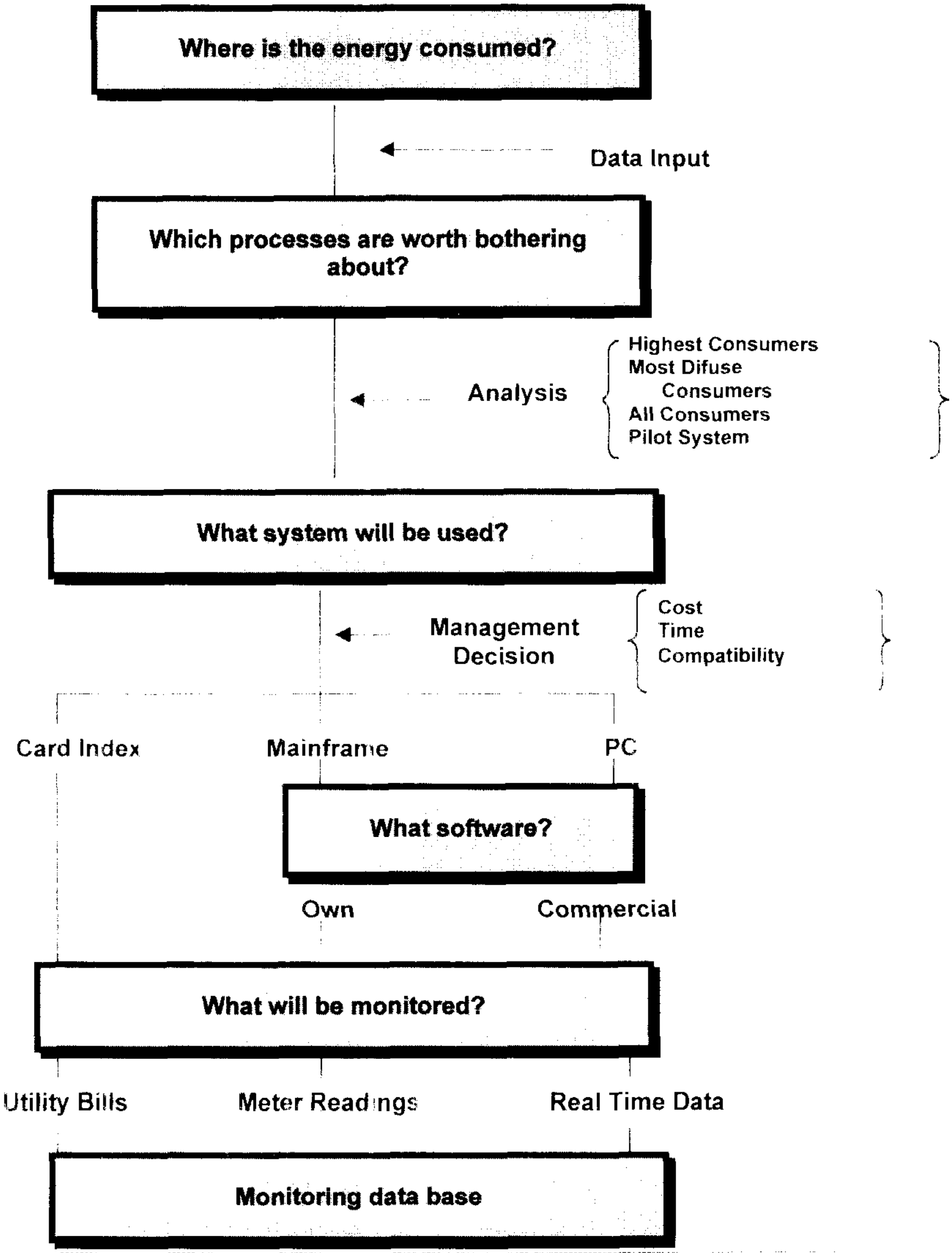
The use of low-cost waste heat reduces fuel consumption by $40,000 to $50,000 a year.

5.7 MONITORING AND TARGETING IMPLEMENTATION GUIDE

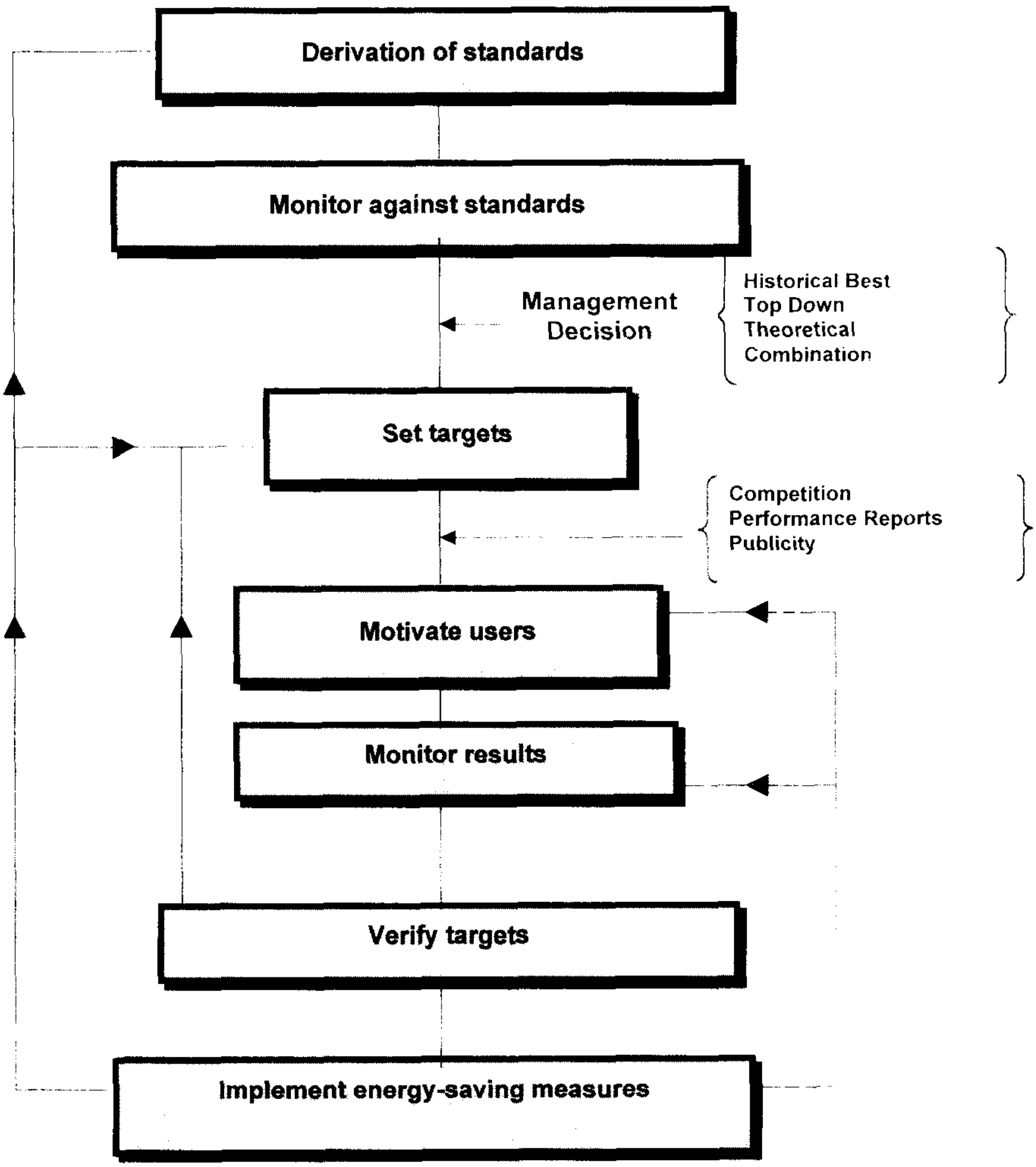
1. The Decision



2. The Set up


Where is the energy consumed?
Data Input
Which processes are worth bothering about?
Analysis
Highest Consumers
Most Difuse Consumers
All Consumers
Pilot System
What system will be used?
Management Decision
Cost
Time
Compatibility
Card Index
Mainframe
PC
What software?
Own
Commercial
What will be monitored?
Utility Bills
Meter Readings
Real Time Data
Monitoring data base

3. The Operation



5.8 ENERGY EFFICIENCY OPPORTUNITIES SELF-ASSESSMENT CHECKLIST

The following is a list of sample questions to answer when establishing the current status. More questions may be formulated from the ***Tips*** in the preceding sections.

Audit questions (mark an "X" in 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?
- ☐ 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 rescheduled 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?

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?
- ☐ Is 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 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?
- ☐ 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 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?

- ❑ What is the blowdown rate and is it at the level recommended by water treatment specialists and 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 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 recirculated 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?
- ❑ 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 refrig-

eration 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?
- ☐ 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 destratification fans in high-ceiling refrigerated areas?

CO_2 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 reprocessing/dumping?
- ❑ Is alkaline solution-based cleaning done in the CO_2 atmosphere?

Electric motors:

- ❑ Is there a policy to replace old motors with energy-efficient motors?
- ❑ Is there a policy to replace smaller motors with energy-efficient motors?
- ❑ Is rewind versus replacement evaluations made when motors fail?
- ❑ Are there any motors running at less than 50% of their rated capacity?

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)?
- ❑ 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 shades?
- ❑ Are external doors being left open for "ventilation"? 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 sys-

tem 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 fan use coupled with equipment use?
- ❑ Is the balance between intake and exhaust air satisfactory? 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?
- ❑ Can any of the lighting systems be replaced with more energy-efficient systems?

Mill room:

- ❑ Are dust extraction systems fitted with variable drives?
- ❑ Are the dust collectors inspected/cleaned regularly?
- ❑ Is steam used only when conditioning malt? 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 spray water recycled?
- ☐ Is there an effective program for cleaning scrubber 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 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 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 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 laboratories?
- ☐ Has the use of waste, unliquifiable 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 good instrumentation to measure operating parameters (temperature, pressure, flow rates, compressed air losses, etc.)?
- ☐ 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?

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