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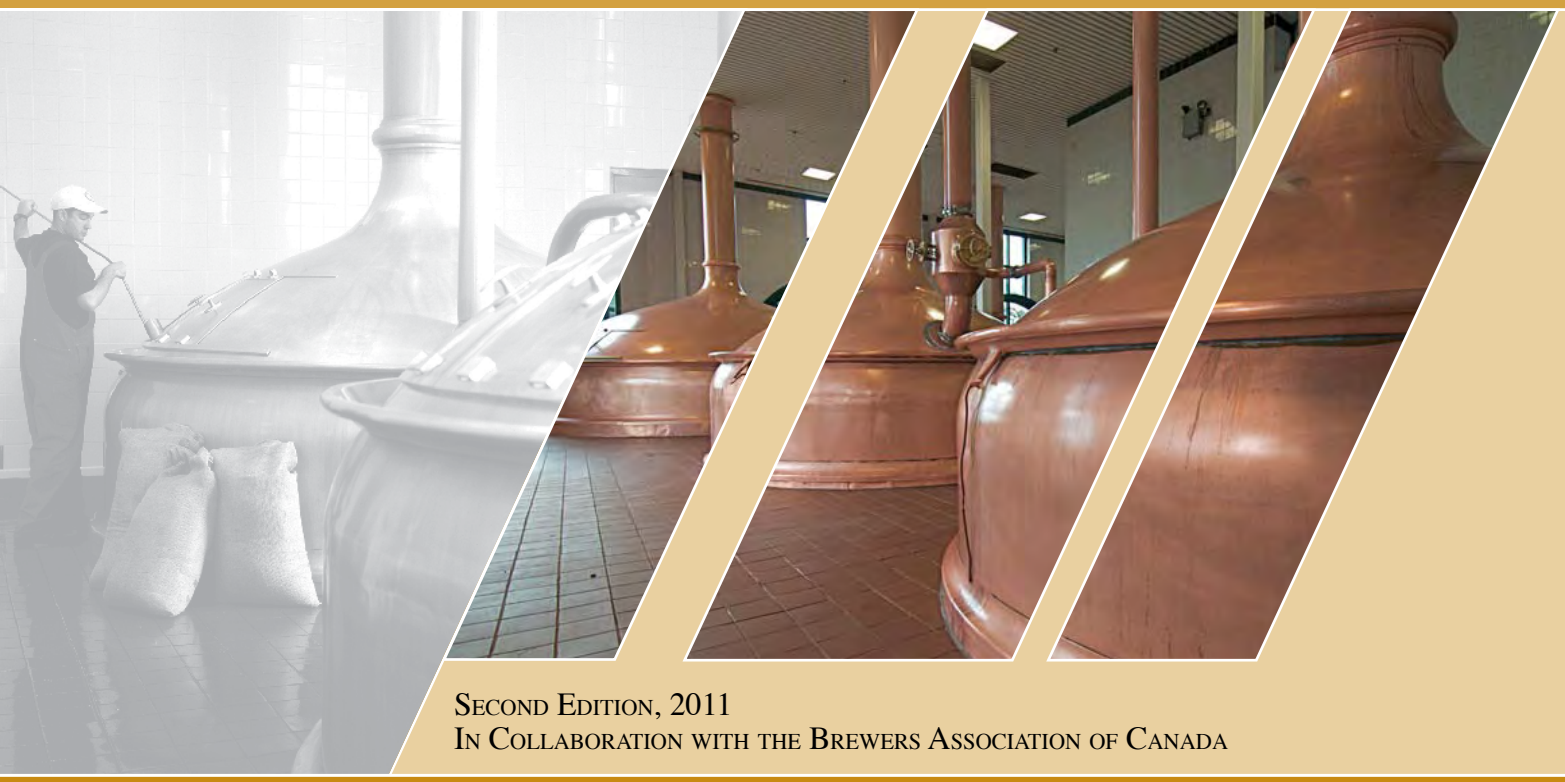
GUIDE TO ENERGY EFFICIENCY OPPORTUNITIES IN THE CANADIAN BREWING INDUSTRY



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IN COLLABORATION WITH THE BREWERS ASSOCIATION OF CANADA

CIPEC

Canada

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The Energy Guide Working Group, created by the BAC in 2009, provided important advice on the Guide, and its relevance and usefulness to brewers across a range of production sizes. Last but not least, appreciation is extended to the many brewers whose enthusiastic participation, tips and ideas were most helpful.

Participating Brewers

*Labatt Breweries of Canada
*Yukon Brewing Company
*Sleeman Breweries Ltd.
Tree Brewing / Fireweed Brewing Corporation
Sierra Nevada Brewing Co.
Wellington County Brewery Inc.
Great Western Brewing Company
*Molson Coors Canada
*Moosehead Breweries Limited
Central City Brewing Co.
*Storm Brewing in Newfoundland Ltd.
Vancouver Island Brewery
Heritage and Scotch Irish Brewing
Wellington County Brewery Inc.
Drummond Brewing Company Ltd.

*BAC Energy Guide Working Group

Note: The authors acknowledge the many sources of information, listed in the Bibliography in the Appendix 10.1, from which they liberally drew in revising and updating the Guide.

TABLE OF CONTENTS

FOREWORD
1. INTRODUCTION 2
1.1 Profile of brewing in Canada 4
1.2 Brewery processes 7
2.0 APPROACHING ENERGY MANAGEMENT 10
2.1 Strategic considerations 10
2.2 Useful synergies – systems integration 11
2.3 Defining the program 15
2.4 Resources and support – Accessing help 21
2.4.1 Financial assistance, training and tools 21
2.4.2 Other resources 22
2.4.3 Tools for self-assessment 22
3.0 ENERGY AUDITING 26
3.1 Energy audit purpose 26
3.2 Energy audit stages 26
3.2.1 Initiation and preparation 26
3.2.2 Execution 30
3.2.3 Report 31
3.3 Post-audit activities 31
4.0 IDENTIFYING AND PRIORITIZING ENERGY MANAGEMENT OPPORTUNITIES (EMOs) 34
4.1 Identifying energy management opportunities (EMOs) 34
4.2 Evaluating and calculating energy savings and other impacts of EMOs 35
4.3 Selecting and prioritizing EMO projects 36
4.3.1 Initial scrutiny 36
4.3.2 Risk assessment 38
4.3.3 Project costing 38
4.3.4 Economic model for trade-offs 39
4.4 Developing energy management programs 43

5.0 IMPLEMENTING ENERGY EFFICIENCY OPPORTUNITIES 46
5.1 Employee involvement 46
5.2 Effective communication 47
6.0 MANAGING ENERGY RESOURCES AND COSTS 50
6.1 Energy and utilities costs and management 50
6.2 Monitoring, measuring consumption and setting targets 51
6.3 Action plans – Development, implementation and monitoring 53
6.4 Monitoring and Targeting (M&T) 55
7.0 TECHNICAL AND PROCESS CONSIDERATIONS 60
7.1 Fuels 60
7.2 Electricity 64
7.2.1 Alternate sources of electrical energy 71
7.3 Boiler plant systems 72
7.3.1 Boiler efficiency 73
7.3.2 Environmental impacts of boiler combustion 75
7.4 Steam and condensate systems 81
7.5 Insulation 84
7.6 Refrigeration, cooling systems and heat pumps 86
7.6.1 Refrigeration and cooling systems 86
7.6.2 Industrial heat pumps 90
7.7 Compressed air 93
7.8 Process gases 102
7.9 Utility and process water 104
7.10 Shrinkage and product waste 110
7.11 Brewery by-products 112
7.12 Wastewater 113
7.13 Building envelope 116
7.14 Heating, ventilating and air conditioning (HVAC) 119
7.15 Lighting 123
7.16 Electric motors and pumps 126
7.17 Maintenance 131
7.18 Brewery process-specific energy efficiency opportunities 132

8.0 BREWERY EMISSIONS AND CLIMATE CHANGE 136
8.1 Calculating one's carbon footprint 138
8.2 International carbon footprint calculations 140
9.0 APPENDICES 142
9.1 Glossary of terms and acronyms 142
9.2 Energy units and conversion factors 146
9.3 Calculating reductions in greenhouse gas (GHG) emissions in breweries 148
9.4 Energy efficiency opportunities self-assessment checklist 150
9.5 "Best practices" in energy efficiency as volunteered by small brewers 158
9.6 Specific primary energy savings and estimated paybacks 160
10.0 REFERENCES 166

LIST OF FIGURES

1-1 Brewery: Total energy and production output (1990-2008) 4
1-2 Brewery: Energy intensity index (1990-2008) 5
1-3 Brewery: Energy sources in Terajoules per year (1990-2008) 6
2-1 Linear view of an energy management system 11
2-2 Energy management system at a glance 16
2-3 Categories for energy management opportunities (EMOs) 18
4-1 Economic modeling tool 40
7-1 Load shedding 66
7-2 Load shifting 66
7-3 Effect of air temperature on excess air level 74
7-4 Options for energy efficient pump operation 127
8-1 Total CO_2e emissions in Canadian brewing industry 136
8-2 CO_2e intensity in Canadian brewing industry 137

LIST OF TABLES

4-1 Long list of EMO projects (example) 36
4-2 Cost estimation accuracy 39
6-1 Profit increase from energy savings 56
6-2 Deployment of M&T (example) 57
6-3 Installation of energy and utilities meters (example) 58
7-1 Comparison of fuel types 61
7-2 CCME NO_x emission guidelines for new boilers and heaters 76
7-3 Typical NO_x emissions without NO_x control equipment in place 77
7-4 Steam leakage losses 82
7-5 Cost of compressed air leaks 94
7-6 A U.K. specific water consumption survey 104
7-7 Water leakage and associated costs and losses 106
7-8 Energy waste – Process problems and solutions 111
7-9 Minimum thermal resistance of insulation 116
7-10 RSI / R insulation values for windows 117
8-1 Global Warming Potential (GWP) of the emissions 139
9-1 Greenhouse gas emission factors by combustion source 148
9-2 Average CO_2 emissions for 1998, by unit of electricity produced 150
9-3 Primary energy savings and estimated paybacks for process-specific efficiency measures 161
9-4 Specific primary energy savings and estimated paybacks for efficiency measures for utilities 162

FOREWORD

Energy Efficiency Opportunities in the Canadian Brewing Industry is a joint project of the Brewers Association of Canada (BAC) and Natural Resources Canada (NRCan). It is a revised and updated second edition of the original with the same title produced by Lom & Associates Inc., released in 1998 and reprinted in 2003.

The purpose of this new version is to recognize the current activities undertaken by the Canadian Brewing Industry and individual companies of all sizes with regard to energy use, greenhouse gas reductions and the conservation of water. It identifies opportunities for improvements in these areas together with current data from Canada and abroad. The Guide is also intended to assist in the development and achievement of voluntary sector energy efficiency targets, under the auspices of the Canadian Industry Program for Energy Conservation (CIPEC). The BAC is a member of CIPEC representing the brewing industry sector.

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

Many of the opportunities for achieving substantial energy and financial savings are often missed, even though advice is available from many sources. Barriers to energy efficiency include an aversion to new technology and a lack of awareness about the relative efficiency of available products. There is often inadequate information on the financial benefits or a strong preference for familiar technologies with an overemphasis on production concerns.

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

The development and release of this revised Guide demonstrates in practice the industry's deep commitment to protecting the environment, including the reduction of greenhouse gases, and the intelligent management of Canada's resources.

> This Guide provides many ideas and tips on how to approach the issue of improving energy efficiency in brewery operations and what to do to achieve it. It is not a scientific or theoretical guide, nor does it purport to be an operations manual on energy management for breweries. It should serve as a practical, one-stop source of information that will lead facilities in the right direction towards getting the help they need.

Regardless of the type and size of the operation or its specific circumstances, the Guide offers ideas that can be adapted to situations or solutions to specific problems. It will allow companies to successfully implement energy efficiency improvements in the brewery sector.

Modern energy management involves many inter-related energy-consuming systems. We suggest that you begin by going through the entire Guide for an initial overall view.

Note

Usage of historically derived measures such as the practically sized hectolitre – hl (100 Litres) – are commonplace within the brewing industry. The usage of the Canadian barrel (= 1.1365 hl) is on the wane. For the purpose of standardization and to facilitate international and inter-industry comparisons, the international SI (metric) system is used wherever possible throughout this Guide.

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

1

INTRODUCTION

1.0 INTRODUCTION

When the Guide was first published in 1998, it provided the first cohesive description of what can be done in a Canadian brewery to reduce the enormous energy load that beer production entails. It obviously filled a need as first edition hard copies were soon gone and a reprint was produced in 2003.

In March/April 2010 the Brewers Association of Canada (BAC) surveyed a number of small breweries in Canada and found that even when the opportunities for energy savings are great, they are not used to good advantage. Some of the reasons included:

- lack of support from management
- energy issues not seen as a priority
- financial, manpower and time constraints, etc.
- no defined accountability
- lack of information
- unaware of opportunities that exist

There is significant potential for increased uptake in energy efficiency practices within the Canadian brewing industry and this updated Guide should help a practicing brewer or any industry that is interested in conserving energy to get the necessary information. As before, the publication's structure and content assumes that the reader already has basic knowledge of brewery operations and processes. Yet, it is written in a way that will provide sufficient information even to members of supporting functions in breweries, both large and small. The point is to generate good understanding of the energy use issues by all brewery staff and obtain their support in addressing them effectively. Because modern energy management involves many inter-related energy-consuming systems, it is suggested that the entire Guide be read first to get an overall view of its content.

Guide layout

The first section looks at the profile of brewing in Canada as well as brewing processes. This is followed by a plan to set up a successful energy management approach, including information on training, tools and resources. It describes the scope of an energy audit and the steps involved, and provides guidance on selecting and costing projects as well as assessing risks or deficiencies. Monitoring and measuring energy, the consumption of utilities and target setting is also given more attention than in the previous Guide. This new version also provides additional information on the relationship between the use of energy and the generation of greenhouse gases in the brewing industry.

A significant section of the Guide (Section 7.0 Technical and Process Considerations) is devoted to potential opportunities to improve energy efficiency in brewery processes, and provides many ideas and tips on how to approach the issue of improving energy efficiency in brewery operations and what to do to achieve it.

Section 7.0 is roughly divided into three categories:

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

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

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

Throughout the Guide, small brewers' concerns have been incorporated as well as best practice tips. Where appropriate and available, references and case studies have been inserted into the text at logical points. Results from the survey of small brewers and from the technical survey of energy use among all brewers in Canada have been selected for illustration. The information provides some insight into the current status of energy conservation effort in Canadian breweries.

Note

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

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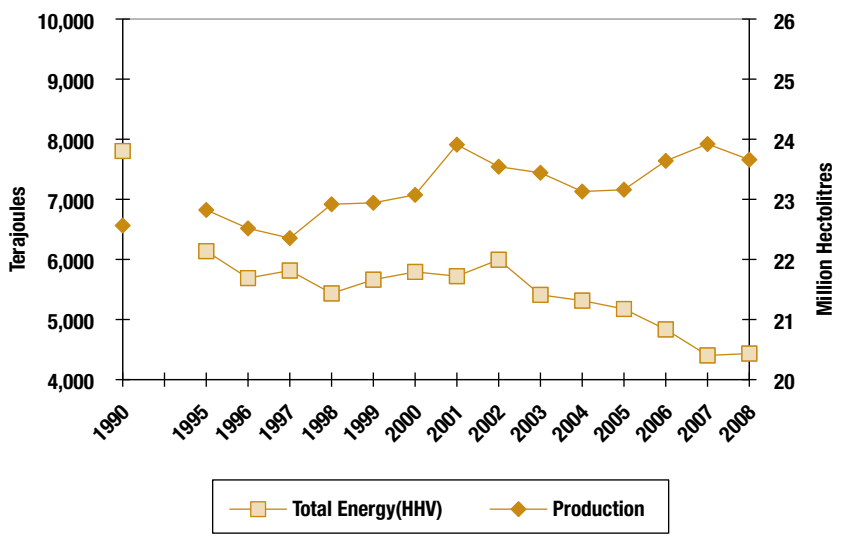
Regardless of the type and size of the operation and its specific circumstances, the Guide will offer ideas that can be adapted to a particular situation or offer a solution to a particular problem. It will allow companies to successfully implement energy efficiency improvements.

1.1 PROFILE OF BREWING IN CANADA

There are some 160 breweries, large and small, currently operating in Canada. Total production, of which the share of small breweries (annual output under 200 000 hl) is about 10 percent, is shown in Figure 1-1.

Figure 1-1 Brewery: Total energy and production output (1990-2008)



NAICS = North American Industry Classification System

Data Sources: Energy Use – Statistics Canada, *Industrial Consumption of Energy Survey,* Ottawa. December 2009; Production – Brewers Association of Canada, Ottawa. October 2009.

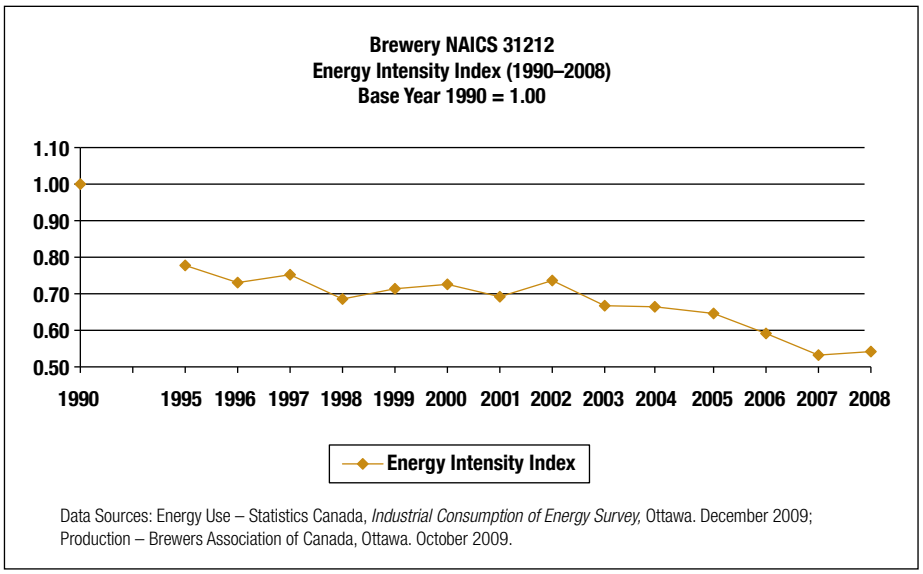
The cost of energy and utilities typically constitutes 3 to 8 percent of a brewery's general budget, depending on brewery size and other variables. Natural gas remains the fuel of choice at 65 percent, followed by electricity at 24 percent. The use of other fuels such as heavy (bunker) oil and middle distillates is not widespread. In recent times, electricity consumption seems to be showing an upward trend. This change appears consistent with other sectors in Canadian manufacturing. (BAC figures)

In Canada, energy conservation efforts were first confined to individual brewing companies. In 1993, the Canadian Industry Program for Energy Conservation (CIPEC) established the Brewery Sector Task Force, which attempted to coordinate efforts and promote information exchange on how to conserve energy, water and other utilities in breweries. As shown above, the Task Force soon started to yield results. (Note: Results were, and still remain, 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 the output of large breweries.)

A well-run brewery would use 8 to 12 kWh electricity, 5 hl water, and 150 megajoules (MJ) fuel energy per hectolitre (hl) of beer produced. For example, one MJ equals the energy content of about one cubic foot of natural gas, or the energy consumed by one 100-watt bulb burning for almost three hours, or one horsepower electric motor running for about 20 minutes. **150 MJ/hl results in the production of 30 kilogrammes (kg) of carbon dioxide equivalent (CO_2e) emissions per hl.**

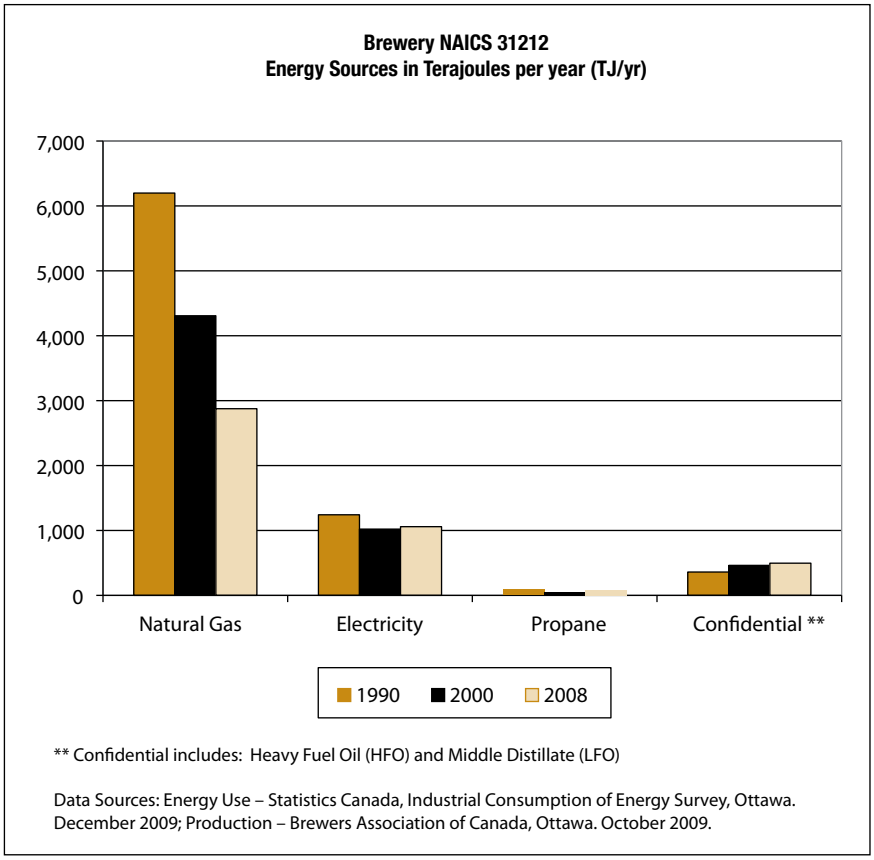
Impressive reductions in energy use have been achieved by the Canadian breweries since 1990. Among the tools to capture this information is the Energy Intensity Index (Figure 1-2). This is a calculated value that represents how energy intensity changes over time. The current year's energy intensity is compared with the base year of 1990.

Figure 1-2 Brewery: Energy intensity index (1990-2008)



Data Sources: Energy Use – Statistics Canada, *Industrial Consumption of Energy Survey,* Ottawa. December 2009; Production – Brewers Association of Canada, Ottawa. October 2009.

Figure 1-3: Brewery: Energy Sources in Terajoules per year (1990-2008)



The drop in energy use, by fuel type, is also revealing (see Figure 1-3). The "**Confidential" category includes Heavy Fuel Oil (HFO) and Middle Distillate (Light Fuel Oil – LFO). The drop in natural gas consumption was the main contributor to reducing the Specific Energy Consumption (SEC) from the average **SEC of 346 MJ/hl in 1990 to 187 MJ/hl in 2008** – an impressive achievement.

This Guide focuses on helping breweries to further reduce their energy and water consumption. An illustration of the objectives is provided by the most recent (2007) survey of 143 large breweries (>500 000 hl/y), conducted by Campden BRI, UK, and KWA, Netherlands. Mean energy consumption was 229 MJ/hl, with the top 10 percent (decile) at 156 MJ/hl. For example, the pre-merger Anheuser Busch averaged 194; SAB-Miller >150; Asahi and Grupo Modelo, both, 217 MJ/hl.

Utility management is an ongoing concern in any brewery. Since the primary goal is financial savings, managers must understand economic principles and run their department as if it were their own business. Nowadays, competitive pressures and narrow profit margins make energy and utilities management all the more important. While financial gains from energy efficiency improvements may seem modest in relation to the value of turnover or the overall budget, they can have a significant bearing on the brewery's net profit. Energy and utilities costs should be viewed as an important part of a brewery's controllable costs; this Guide should help in the task.

1.2 BREWERY PROCESSES

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

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

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

Brewing yeast metabolizes the usable sugars of the wort into alcohol and carbon dioxide (CO_2) and also into new yeast mass. In the fermenter the metabolism releases a good deal of heat that has to be removed by chilling. 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. A part of the yeast still suspended in green beer settles in the storage tank or is removed by centrifuging during the transfer. In the storage tank, it is further chilled, depending on its alcohol content, to as low a temperature as possible, usually to -1°C to -2°C. After a (flavour) maturation period (called "lagering" or "aging"), the beer is filtered, carbonated and is ready in the packaging cellar for packaging into bottles, cans or kegs. Some types of beers, particularly those produced in small/pub breweries, do not get filtered. The filtration is purely a cosmetic process.

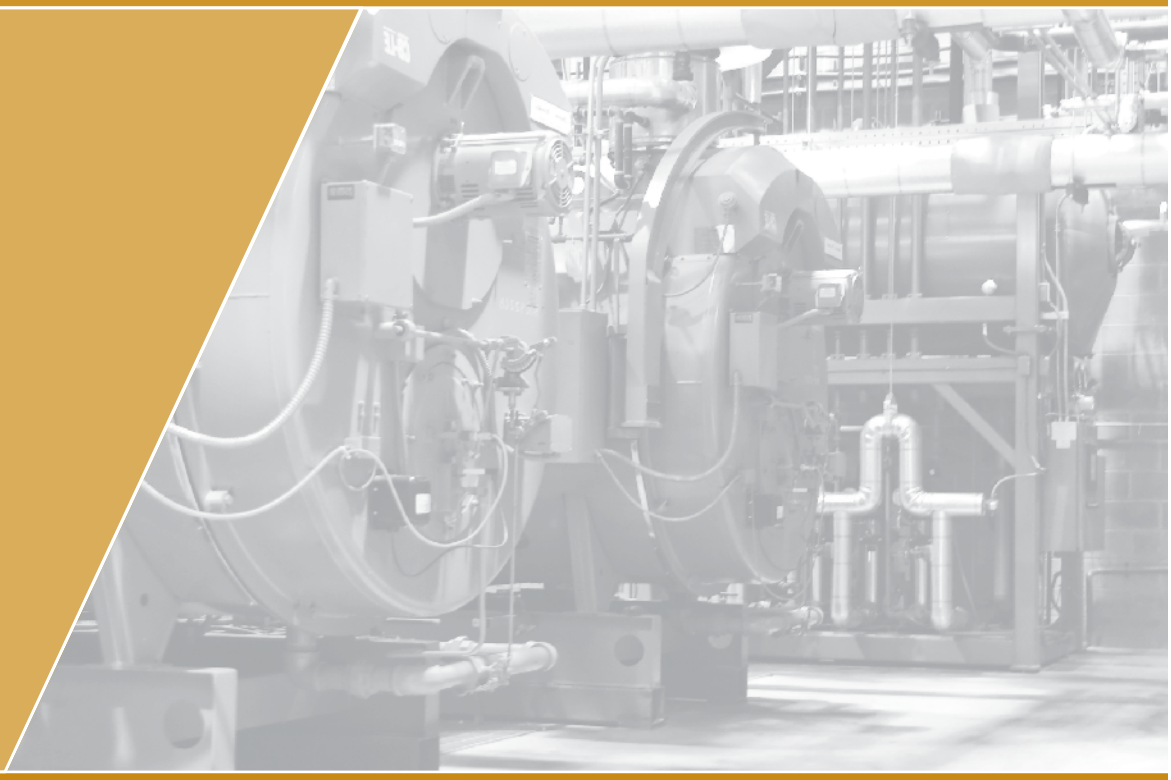
In Canada, virtually all domestic beer bottles are returnable. Therefore, they must be cleaned prior to reuse. Returned bottles make multiple passes through bottle washers ("soakers") that consist of baths and sprays of a hot caustic soda solution. At the exit, bottles are cooled with sprays and rinses 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, a caustic solution and steam.

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

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

2

APPROACHING ENERGY MANAGEMENT



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2.0 APPROACHING ENERGY MANAGEMENT

2.1 STRATEGIC CONSIDERATIONS

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

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

To put energy efficiency into perspective, if your energy budget is $1 million, and you could save just 10 percent through better energy practices, ask yourself: "How many hectolitres do I have to sell to earn the $100,000 – net?"

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

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

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

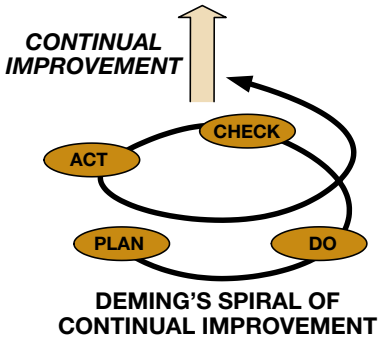
1. Firm commitment of top management
2. Clearly defined program objectives
3. Organizational structure and definition of responsibilities
4. Provision of resources – people and money
5. Measures and tracking procedures

And regular progress review.

These points are further expanded on in Figure 2-1 and in Section 2.3 – Defining the program.

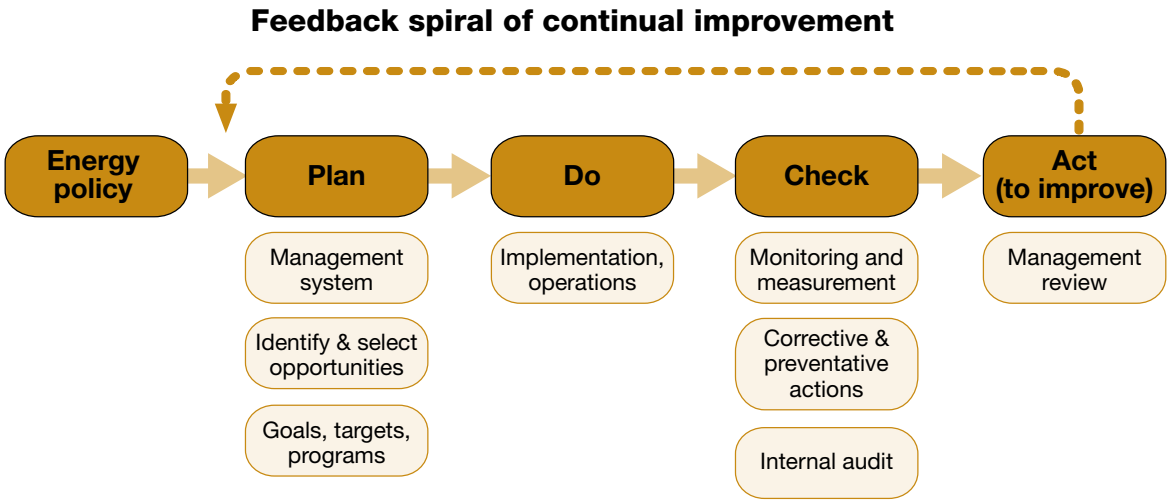
2.2 USEFUL SYNERGIES – SYSTEMS INTEGRATION

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



In a linear view of an energy management system (Figure 2-1), starting with a policy, these elements include the following main blocks of activities:

Figure 2-1: Linear view of an energy management system



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

- ISO 9001:2008 – management system for quality
- ISO 14001:2004 – environmental management system
- OHSAS 18001:2007 – occupational health and safety assessment system, and, within the context of energy efficiency improvements, discussed here, also the draft of the brand new
- ISO 50001 – Energy Management Systems Standard

12

Among other relevant norms and guidelines are

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

Standard	Description
ISO 9001:2008	**Management system for quality** In breweries as in any other business, the mantra "Satisfy your customer" drives the quest for quality. More and more breweries worldwide have adopted the standard, along with the hundreds of thousands of various businesses worldwide that have embraced the standard since its introduction in 1987. In many industries, certification to ISO 9001 has become a requirement and a condition for staying in business.
ISO 14001:2004	**Environmental management system** The implementation of an environmental management system (EMS) will result in continually improving environmental performance. The specification of the standard is based on the concept that the organization will periodically review and evaluate its EMS to identify opportunities for improvement. Although some improvements in environmental performance can be expected on the basis of the adopted systematic approach of the standard, EMS is primarily a tool that enables an organization to achieve and systematically control the level of performance it sets for itself. The organization has the freedom and flexibility to set the boundaries of its EMS. The system's requirements and criteria are also suitable to occupational health and safety, and the energy efficiency improvement effort.
OHSAS 18001:2007	**Occupational health and safety assessment system** The standard has been adopted by many countries, but has not yet become an international standard. It offers the means to systematically, consistently and proactively manage workplace hazards to achieve long term goals of ensuring the health and safety of all employees. Although much broader in its scope, its structure closely emulates that of ISO 14001.
ISO 50001	**Energy Management Systems Standard** In any brewery, energy efficiency enhancement efforts are just one segment in the drive to improve profits, achieve higher quality operations and products, and demonstrably implement responsible environmental behaviour throughout the company. The new energy management system standard enables systematic and consistent approach to the effort. It is a new tool coming at the right time.

Standard	Description
HACCP	**Hazard Analysis Critical Control Points** Since beer is considered a "food," HACCP applies to its production. HACCP, which can also be used as a quality management tool, is a food safety program. It is designed to ensure that at each stage of the production, packaging and distribution processes, any possible hazard that could impact the product and cause it to be contaminated and/or become injurious to health has been identified and eliminated. All brewing and packaging materials, brewing and packaging operations, transportation, warehousing and retail operations are scrutinized. From the point of view of energy and utilities, protection from contaminated and/or tainted water, steam, condensate and process gases must be assured. HACCP works with ISO 9001 as a quality management tool. Where more generic, all-encompassing ISO systems have not been implemented, the HACCP is a quality system in its own right. ISO and HACCP do not have to be run as two separate systems. The Brewers Association of Canada has developed an HACCP program applicable specifically to brewers. Additional information: www.brewers.ca/default_e.asp?id=125
ISO 31000:2010	**Risk management principles, framework and application** The eminently useful standard (explained by Canadian Standards Association norm CSA/Q850-10) is applicable to any situation where hazard exists and risk needs to be assessed (e.g. investment decisions, environmental aspects, occupational health & safety, selection of priorities, etc.). In this context, it is interesting to note that Courage Brewery (U.K.) used a dual risk assessment of the hazard occurring with control measures in place at a specified process step compared with the probability of that hazard getting through to the final product with subsequent control measures in place. Except for the new ISO 31000:2010, the implementation of all management systems listed above can be independently audited by accredited bodies (called "Registrars") **and certified**. The certification – synonymously called "registration" – is the recognition of the compliance to the rigorous requirements of a standard. The certificate becomes a public document. All of these programs have something in common: the desire to improve quality in the broadest sense of the word. Their systematic, structured, consistent and thought-out approach makes them valuable.

14

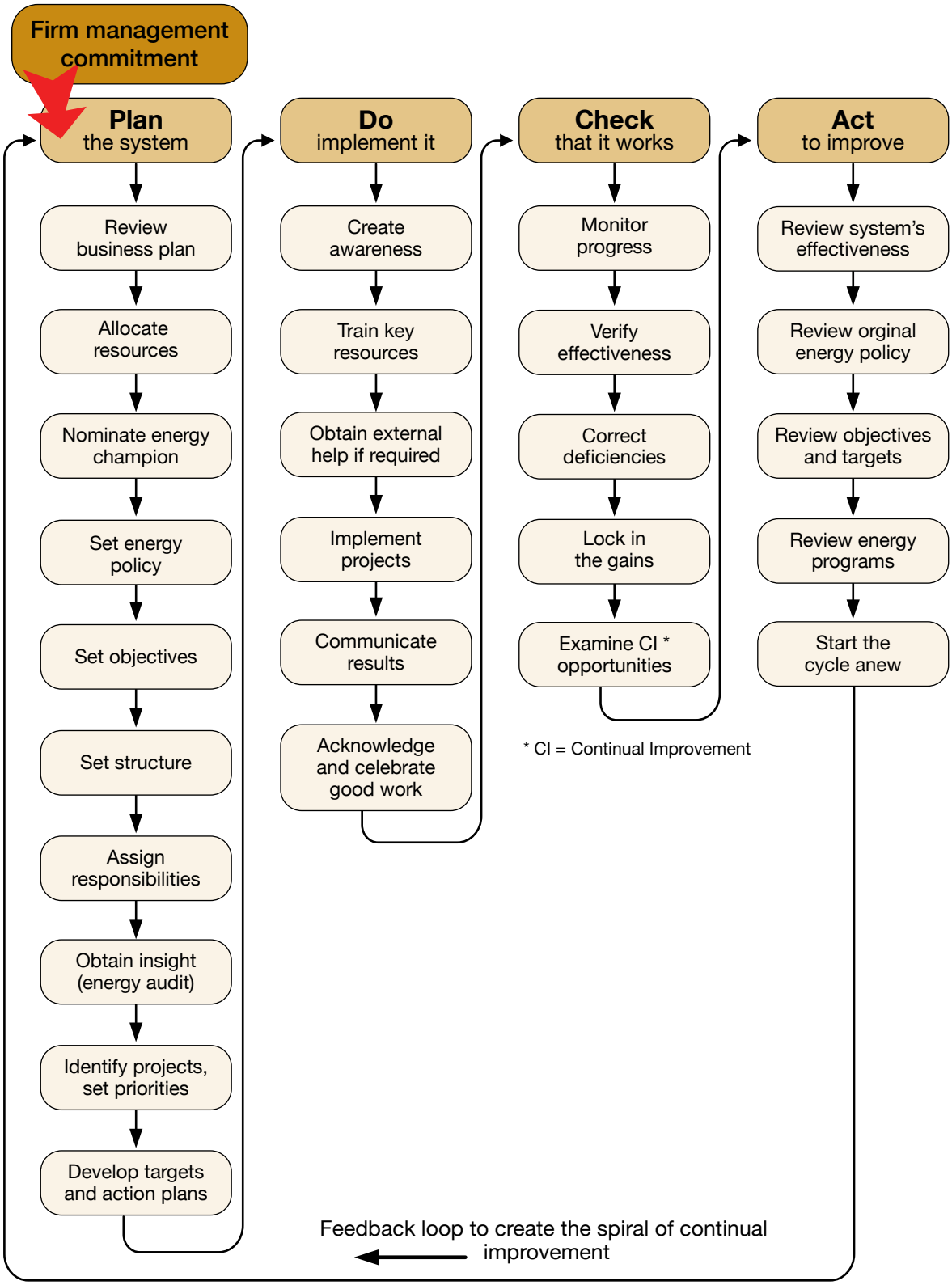
Replace programs with system approach	Programs are limited in time. Often, various programs are initiated and launched in a brewery in isolation from others. Sometimes programs that have not been well planned and/or have not received sufficient support will flounder and die off. "Flavour of the month," employees will say. On the other hand, systems continue to operate indefinitely, using programs to achieve specific goals within the systems. Programs are made an integral part of the overall improvement strategy.
Take advantage of compatibility and synergies	The ISO standards listed above are fully compatible. The similar structure of modern management system standards – by now pretty well perfected – enables systems integration in a single enterprise-wide management system. For example, the energy management system need not stand alone. Many of its elements can be integrated with similar elements in other systems. That is profitable: overall management system becomes streamlined, simpler and activities interwoven, giving rise to valuable synergies and higher effectiveness.
Integration of systems makes sense	Integrating systems sharing a common philosophy into an overall management scheme makes sense because doing so offers: 1) Unified management system: • efficient • duplication eliminated or reduced • proactive, predictable, consistent, modifiable, understood 2) Training: • efficiency and effectiveness • conflicting training requirements minimized • multi-disciplined approach • all-in-one program 3) Resources: • best utilization of people, energy, and materials in the context of a single overall management system 4) Improved compliance posture: • increased confidence by regulators • tangible demonstration of commitment 5) Savings on costs of: • materials and labour • energy • product-in-process, finished product • waste • contingency liability costs • public relations and goodwill

Advantages of system registration	The quantifiable benefits of a management system's implementation and subsequent registration can be summarized as follows: • improved documentation of process procedures and work instructions • improved communication throughout the organization • improved product, process or service performance and customer satisfaction • prevention of errors in all operations • improved productivity, efficiency and cost reduction • improved quality of work and employee satisfaction • public recognition leading to improved market share

2.3 DEFINING THE PROGRAM

Figure 2-2 shows the generic at a glance plan of setting up an energy management system. It represents an ideal, proven scenario, where the various steps are approached in a rational, reasoned and systematic manner. This system will enable you to launch successful energy management programs. However, the full description of the strategy may not fit the resource situation in smaller breweries.

Figure 2-2: Energy management system at a glance



Management commitment

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

Review business plan and allocate resources

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

The amount of time and effort allowed to the persons responsible for implementing the energy management program will ultimately determine its effectiveness. Therefore, adequate operational funding is essential. Without such funding, or freeing up people to do the work, not much will be achieved.

Nominate the energy champion

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

Set energy policy – create awareness

The launch of the energy management program should be supported by a strong policy statement from the brewery's chief executive to the staff. Develop the energy policy in consideration of other company commitments, policies (quality, production, environment, health and safety, etc.) and strategic goals.

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

An excellent "*Toolkit for Your Industrial Energy Efficiency Awareness Program*" is available on request from NRCan. Send an e-mail to info.ind@nrcan-rncan.gc.ca.

Decide on objectives

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

Set structure and assign responsibilities

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

In smaller breweries, all management staff should necessarily have duties related to reducing energy consumption.

Develop action plans

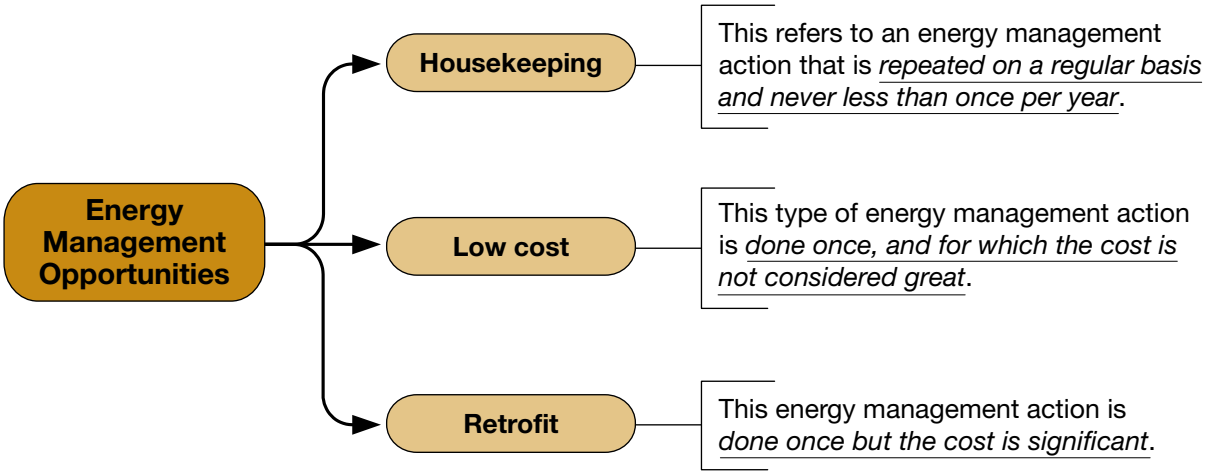
An action plan is a road map. It serves as a project management and control tool that indicates the responsibilities, specific tasks, resources (money, people, training, etc.) and timelines for individual projects and their respective stages. Several project management software applications such as Microsoft Project Manager are available on the market to facilitate the creation of a project plan. Gantt charts are used to monitor and control project fulfillment, costs, etc.

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

- Housekeeping
- Low cost
- Retrofit

We will use this classification, shown in Figure 2-3, to describe the EMOs in Section 7 – Technical and process considerations.

Figure 2-3: Categories for Energy Management Opportunities (EMOs)



Train key resources

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

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

NRCan offers a number of specific energy efficiency improvement workshops across Canada. For information visit Dollars to $ense Energy Management Workshops. Other sources of training are available through utility companies, etc.; see Chapter 2.4 – Accessing external help.

Implement projects

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

Take advantage of the various synergies for even greater energy savings.

Communicate the results

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

Acknowledge and celebrate good work – celebrate success

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

Monitor progress

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

Verify effectiveness

In the case where a technical solution has been implemented in a project, the verification of effectiveness may be as simple as the continuous monitoring of performance. When the project involves behavioural change (e.g. turning off idle equipment), verification of the measure's effectiveness should be performed after some time has elapsed (e.g. a month or two).

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

Correct deficiencies

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

Information gained from the monitoring of data, the input from the Energy Management Centre (EMC) and other control systems, the review of results, and the verification of the project's effectiveness may indicate that a corrective action is required. The energy management champion is responsible for arranging the corrective action with the EMT and the personnel from the respective area involved. The root cause of the deficiency will be determined and the required corrective action will be initiated. Future energy efficiency projects will benefit from the lessons learned.

Remember to document it, as required. This keeps track of things while the history serves as a learning tool for avoiding shortcomings in other projects.

Lock in the gains

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

Examine continual improvement opportunities

Look for opportunities to implement specific energy conservation measures in other areas – where the need for them may have been overlooked and conditions are similar. This "feed forward" mechanism amounts, in fact, to a preventive action.

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

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

Review the Energy Management System effectiveness

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

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

This step ensures the continued relevance and currency of the energy policy. Supporting it are objectives and targets. As they change in time, their review is required to ensure that priorities are maintained taking into account the existing conditions. Yearly or semi-annually is probably the best frequency for reviews.

The energy efficiency improvement program and action plans are "living" documents. Their updating and frequent reviewing are necessary since old projects are implemented and new ones are initiated, and because business conditions change. The energy management champion leads this activity, and needs to get input from the EMC and other control systems, subsequently seeking approval for updates from the management team.

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

2.4 RESOURCES AND SUPPORT – ACCESSING HELP

The following is a list of the resources available for industry. It includes information, programs and tools offered by the Government of Canada, provincial and territorial governments, major Canadian municipalities and major electric and gas utilities and companies. Much of this information is available through Natural Resources Canada's (NRCan's) Web site: cipec.gc.ca.

2.4.1 Financial assistance, training and tools

NRCan, CIPEC, and the Office of Energy Efficiency (OEE) offer resources and services for industry:

Assistance and training

- financial assistance for implementation of an ISO 50001 - Energy Management Systems Standard project, process integration and computational fluid dynamics studies
- tax incentives for investments in systems that generate electricity and/or produce heat
- Directory of Energy Efficiency Programs for Industry found across Canada offered by provincial, territorial, municipal and electric and gas utility companies
- Dollars to $ense Energy Management Workshops and opportunities to have them delivered on site and customized to meet specific company needs

Resources and tools

- Industrial Energy Efficient Equipment web page has valuable information to assist in the selection and purchase of energy efficient products for industrial facilities
- technical guidebooks
- *Heads Up CIPEC* – an e-newsletter with the latest energy efficiency information
- support for benchmarking studies and employee awareness initiatives
- Publications – a virtual library with energy-related literature, brochures and pamphlets
- tools and calculators

2.4.2 Other resources

The Internet is an inexhaustible source of information for training programs on energy efficiency offered by colleges and other institutions. As mentioned above, NRCan's Directory of Energy Efficiency Programs for Industry provides a list of programs across Canada offered by provincial territorial, municipal and electric and gas utility companies at the following Web site: oee.nrcan-rncan.gc.ca/industrial/financial-assistance/programs.cfm

2.4.3 Tools for self-assessment

Some tools and programs have been mentioned above. However, there are some other sources of help for performing a self-assessment:

Steam system assessment tool

Downloadable software package to evaluate energy efficiency improvement projects for steam systems. It includes an economic analysis capability. Contact: U.S. Department of Energy, Office of Industrial Technologies, at www1.eere.energy.gov/industry/bestpractices/

Steam system scoping tool

Downloadable software package. Spreadsheet tool to identify energy efficiency opportunities in industrial steam systems. It includes an economic analysis capability. Contact: U.S. Department of Energy, Office of Industrial Technologies, at www1.eere.energy.gov/industry/bestpractices/

Optimizing the insulation of boiler steam lines

Downloadable software package to determine optimized insulation of boiler steam lines. The program calculates the most economical thickness of industrial insulation for a variety of operating conditions. It makes calculations using thermal performance relationships of generic insulation materials included in the software. Contact: U.S. Department of Energy, Office of Industrial Technologies, at www1.eere.energy.gov/industry/bestpractices/

Pump system assessment tool (PSAT)

Downloadable software package to help industrial users assess the efficiency of pumping system operations. PSAT uses achievable pump performance from the Hydraulic Institute's standards and motor performance data from the MotorMaster+ database to calculate potential energy and associated cost savings. Contact: U.S. Department of Energy, Office of Industrial Technologies, at www1.eere.energy.gov/industry/bestpractices/

MotorMaster+

Downloadable software package for energy efficiency motor selection and management, including a catalog of over 20 000 AC motors. It contains motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting and environmental reporting capabilities. Contact: U.S. Department of Energy, Office of Industrial Technologies, at www1.eere.energy.gov/industry/bestpractices/

AirMaster+

Downloadable software package. It is a tool to maximize the energy efficiency and performance of compressed air systems through improved operations and maintenance practices. Contact: U.S. Department of Energy, Office of Industrial Technologies, at www1.eere.energy.gov/industry/bestpractices/

ENERGY STAR® Portfolio Manager

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

Insulation calculator tool

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

3

ENERGY AUDITING

3.0 ENERGY AUDITING

Why have energy audits?[1] An energy conservation project, yielding a good financial return, should not be undertaken without an audit.

It is likely that without the systematic approach of the audit, the ad-hoc application of energy management would result in many missed opportunities and fail to discover beneficial project synergies.

An energy audit could be formally organized and executed, and its results could be utilized. While such a path may not be taken – especially by smaller breweries due to their modest means – its description may, nevertheless, be useful.

3.1 ENERGY AUDIT PURPOSE

An initial energy audit is a key step that establishes the baseline from which future energy efficiency improvements would be measured. (Other energy audits may be performed later, e.g. to verify achievements or uncover other incremental energy saving opportunities.)

The purpose of an energy audit is to establish and evaluate energy consumption in a brewery, and uncover opportunities for energy savings. To maximize value, an audit should address and express in quantified ways:

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

A list of practice-proven steps in energy auditing follows.

3.2 ENERGY AUDIT STAGES

3.2.1 Initiation and preparation

Defining the audit scope

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

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

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

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

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

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

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

Selecting auditors

The audit process and its results must be credible.

The determination of the audit scope and objectives will provide an idea of the duration of the audit. This, in turn, will help to ascertain how many people would be needed and for how long. For smaller operations, all that is needed is a competent individual with suitable technical training, and good overall knowledge of the brewery's operations, auditing process and techniques, and particularly of an energy audit. It helps if the person likes to work with computers.

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

Will it be necessary to hire an experienced energy consultant to do the audit or is there such a person in-house? Often, a company looks at cost as a major factor when choosing someone. On the surface, employing in-house brewery staff would be considerably less costly than hiring a private consultant. However, adding the audit task to a person's regular workload could interfere with

routine work, leading to errors. There would inevitably be a learning curve which may mean it could take twice as much time to complete the audit. As well, staff may be biased or may be oblivious to certain aspects of their own operations. On the other hand, private consultants probably have broader experience and knowledge of similar operations or situations which are transferable to other locations they are auditing. The pros and cons of both sides should be considered.

Assessing budget and audit duration

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

Timing of the audit

Plan and conduct the energy audit with the intention of determining energy inefficiencies in the brewery processes as well as energy losses in the "waste" streams.

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

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

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

Determine the production baseline

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

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

Gathering available information

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

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

Getting the tools

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

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

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

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

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

3.2.2 Execution

Gathering information

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

While measuring and recording energy consumption data, examine current brewery practices and procedures. Interview the workers and staff. Observe how the job is performed. If necessary and feasible, ask for a demonstration. Compare information obtained from different sources; verify its validity. The aim here should be to obtain objective and verifiable information.

Balances

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

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

The balances include:

- **power balance**
- **natural gas (and/or oil) balance**
- **steam and condensate balance**
- **water balance**
- **material balance (raw material to saleable beer – extract losses)**
- **etc.**

Practical production considerations

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

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

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

The auditor should also pay attention to the process equipment and how it is used when accounting for energy losses, e.g. assess washers and pasteurizers, conveyors, ventilation, the state of their repair, etc. Energy wastage has a major bearing on the brewery's bottom line.

3.2.3 Report

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

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

The audit report will typically contain:

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

3.3 POST-AUDIT ACTIVITIES

Understanding the audit results

With the delivery of the audit report, the energy audit is considered completed. The results of the report reflect a particular slice of time during which the audit was conducted. Although not absolute, the results can be extrapolated with reasonable accuracy to the average brewery operating conditions. The management team should review the audit report with this in mind and decide on the course of action to be taken.

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

There are two possible energy audit outcomes:

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

4 IDENTIFYING AND PRIORITIZING ENERGY MANAGEMENT OPPORTUNITIES (EMOs)

4.0 IDENTIFYING AND PRIORITIZING ENERGY MANAGEMENT OPPORTUNITIES (EMOs)

4.1 IDENTIFYING ENERGY MANAGEMENT OPPORTUNITIES (EMOs)

After a certain period, a picture will emerge about what can be done in a brewery to improve the way it handles energy use. Inputs may include the following:

- Results of the initial energy audit
- Review of literature, including Web sources
- Information about applicable ideas from other breweries and other industries
- Consultations with NRCan's CanmetENERGY[2] and Office of Energy Efficiency
- Equipment supplier recommendations
- Consultant's advice
- Fresh look at the way the brewery manages its production and operations
- Ideas and suggestions

This may result in a very long list of EMOs. By type, the EMOs fall into these broad categories:

Organizational changes	The influence of **organizational change** on energy conservation is often hidden. It involves changes in planning and scheduling production that allows for a partial or an across-the-board levelling of energy use, hence its better utilization. The point is to try to achieve a more steady-state production output. Granted, this may be a tall order, but the marketing and sales departments can help production staff here.
Process changes	Involves improvements in process equipment and technology that results in reduced energy consumption. The **process change** category will probably be the largest and most capital-intensive. Improvements include changes to throughput capacity, improved quality (product characteristics), process controls, where, typically, efficiency of energy utilization has not been the driving reason. This can be used to justify other projects and upgrade activities (e.g. variable speed drives, high efficiency motors).
Boiler energy efficiency and potential fuel substitution	Entails improvement upgrades to burner systems, monitoring and control of flue gas composition as well as furnace lining and insulation. It focuses on maximizing the efficiency of energy use and selecting the best source of energy (e.g. oil or natural gas). Fuel substitution is a consideration dependent on fuel market availability (e.g. natural gas in Quebec) and long-term prognosis of cost.

[2] *Canada Centre for Mineral and Energy Technology*

Electric power management	Electrical power management is an area which can improve the profit of the brewery quite significantly. It consists of the comprehensive monitoring and control of electrical energy consumption, including peak demand and power factor management and cogeneration (see Section 6.4 – Monitoring & Targeting).
Heat recovery	Heat recovery includes projects that are best viewed in the context of the entire brewery; several energy systems may be involved and synergies are possible to achieve. It involves the reuse of waste heat streams and their integration and prevention of heat losses in all forms (e.g. heat exchanger, insulation).

4.2 EVALUATING AND CALCULATING ENERGY SAVINGS AND OTHER IMPACTS OF EMOS

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

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

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

To organize all this information into a long list of projects, a table can be constructed as shown below (Table 4-1). The columns are self-explanatory, except the Benefits-Cost, where annual energy saved per investment dollar is stated.

Table 4-1: Long list of EMO projects (example)

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

4.3 SELECTING AND PRIORITIZING EMO PROJECTS

At first glance, the projects offering the highest return on investment should be chosen for execution. However, it is not that simple. There are other considerations. Project selection and prioritization is often perceived as a very difficult task. The following is a brief guide, including some **proven decision-making tools** to make the task simple enough for anyone to do. They include:

4.3.1 Initial scrutiny

The initial long list of EMO projects should be scrutinized from different angles. In addition to clearly impractical ideas, which can be rejected out of hand, projects that do not meet the criteria listed below (brewery-specific) will also be discarded. The following criteria will be examined:

Technical feasibility	Evaluate all available information such as • good engineering practice • experience of others, testimonials • supplier information • literature • consultants • technical uncertainties • performance risks

Possible synergies	Can the project be integrated to advantage with others thereby achieving higher benefits (e.g. an upgrade of pasteurizer heat recovery together with improved space heating and ventilation)? If so, try to quantify the benefits of the projects interaction, and compare this to benefits of the individual projects and their sum. Consider various combinations of projects before settling for an optimum group to implement jointly. *The approach described here is considered appropriate because it is comprehensive. However, it is recognized that lack of necessary resources may force a brewery to implement a project without the time and effort required in comparing it to others. Once a project is seen as meeting the energy savings requirements, and clears all the other investment hurdles, there is no reason for delaying it. The advantage of this ad-hoc approach is in the rapid implementation of projects, which start providing ongoing energy savings fast.*
Business risks	See Section 4.3.2 – Risk assessment, below, for details.
Business plan and priorities	Consider also the brewery's business plan (usually over several time horizons – short-, mid- and long-term), business priority objectives, and financial situation. **"The key is not to prioritize what is on your schedule, but to schedule your priorities."** **Steven Covey** Apply the "**first things first**" rule: put emphasis on a proactive, preventive approach to issues and projects, which will allow a departure from the all-too-common firefighting, the crisis management mode of operations. In other words, ask the question: "Is this the right thing to do?"
Project's profitability	1. Assess the total capital cost of the project, including, for example: equipment price, modification, installation, certification installation space 2. Estimate the cumulative annual operating savings of the improvement project such as power, water, natural gas, compressed air, consumables maintenance, spare parts, labour (Of these, energy consumption is the most important factor within the context of energy conservation projects. Note that compressed air, due to the high energy cost involved in its generation, is treated separately.) 3. Calculate the simple payback period on investment and express it in years (months, if less than one year).

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

4.3.2 Risk assessment

All projects involve risk to some degree. Organizations face a wide range of risks such as

- **Financial:** accounting and audit, insurability, credit, insolvency
- **Organizational:** corporate image, human relations
- **External:** market, social change, climate change
- **Regulatory:** regulations, governmental policies
- **Legal:** legislation, statutes, torts, contracts
- **Operational:** production, environment, health & safety, assets

Business risk is a threat that an event, action or inaction will adversely affect an organization's ability to achieve its business objective and execute its strategies successfully. **Business risk management** is a proactive approach that helps owners and managers to anticipate and respond effectively to risk. Not all business risks can be eliminated. To assess whether further effort to reduce risk is meaningful, an acceptable **risk tolerance** level must be established.

Further information on business risk assessment can be obtained from reading the *CAN/CSA-Q850-10 Standard: Risk management or from the similar, new ISO 31000:2010 – Risk management principles, framework and application*. Balance the perspectives from the point of view of safety, environment, legal and regulatory, business and public image. Assess the risk by using the formula (as per *CAN/CSA-Q850-10 Standard*):

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

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

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

4.3.3 Project costing

Note that for initial screening purposes, the "best guess" rough estimates of a project's capital cost are generally sufficient. We are interested in the order of magnitude at this pre-feasibility level based on a preliminary concept. Include a generous allowance for all cost components that should be considered in the project, such as equipment capital costs, installation costs (mechanical, structural, piping and civil engineering, site preparation, existing equipment modifications/removal, electrical, etc.). Make

allowance for indirect costs (such as construction management, contractor's overhead, owner's costs, and consultants) and include generous contingency leeway at this stage. It is understandable that the anticipated accuracy may be off by 50 percent. Use these results for initial ranking.

While it is difficult to predict a brewery's future operations, energy savings projects must be assessed in this context: e.g. future production increases, possible process bottlenecks and anticipated process changes. As the project selection progresses, the preliminary selection can now be subjected to cost estimations, which make project pricing more formal and better researched. Budgetary quotations can be obtained from vendors at this stage. All of the project component costs, as above, must now be carried out in more detail.

When the choices have been narrowed down, greater accuracy for a formal project approval process is required. It means that detailed engineering of the project must be done, which includes drawings, schematic electrical, piping and duct diagrams, issuance of formal requests for proposal to multiple vendors, with all project specifications, etc. The typical relationships and anticipated accuracy levels are shown in Table 4-2 below.

The task will only be considered complete when more accurate costs of the selected project or projects are determined and **possible trade-offs** examined. Choices must be made. There are many considerations, each of which has a cost attached to it, and an optimum solution must be found. That optimum solution should then be the subject of project submission approval.

Table 4-2: Cost estimation accuracy

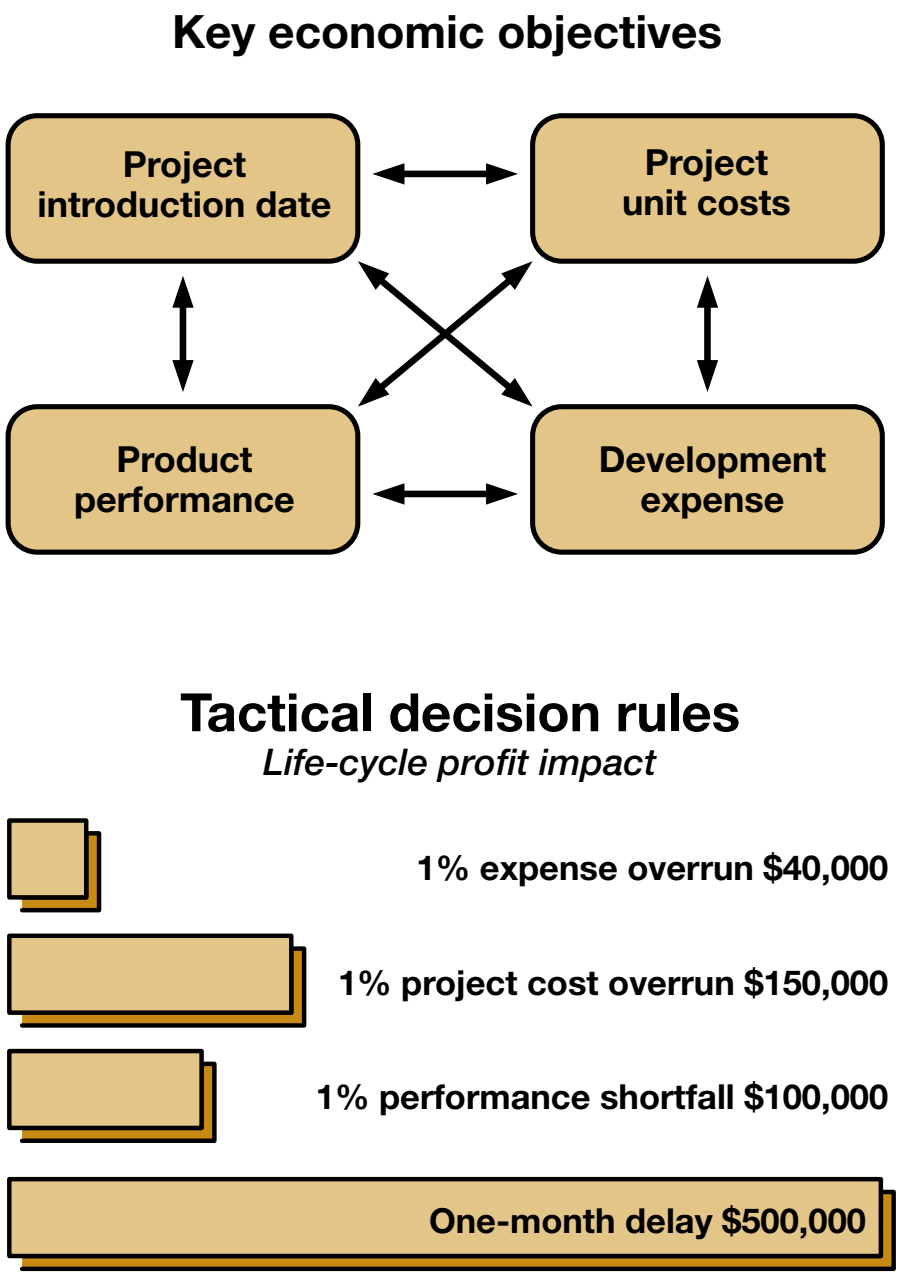
Project stage	Appropriation costs, %	Indirect costs (as % of approp. costs)	Contingency cost (% of total)
Pre-feasibility study	± 40-70	± 30-50	+20
Feasibility study	± 25-30	± 25-35	+ 10-15
Project approval	± 10, ou 0-10	± 20-30	+ 5

4.3.4 Economic model for trade-offs

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

For those disinclined to use computer simulation, another proven, very simple economic modeling tool is available, courtesy of Reinertsen & Associates of Redondo Beach, CA. Do your product development math as shown in Figure 4-1 below.

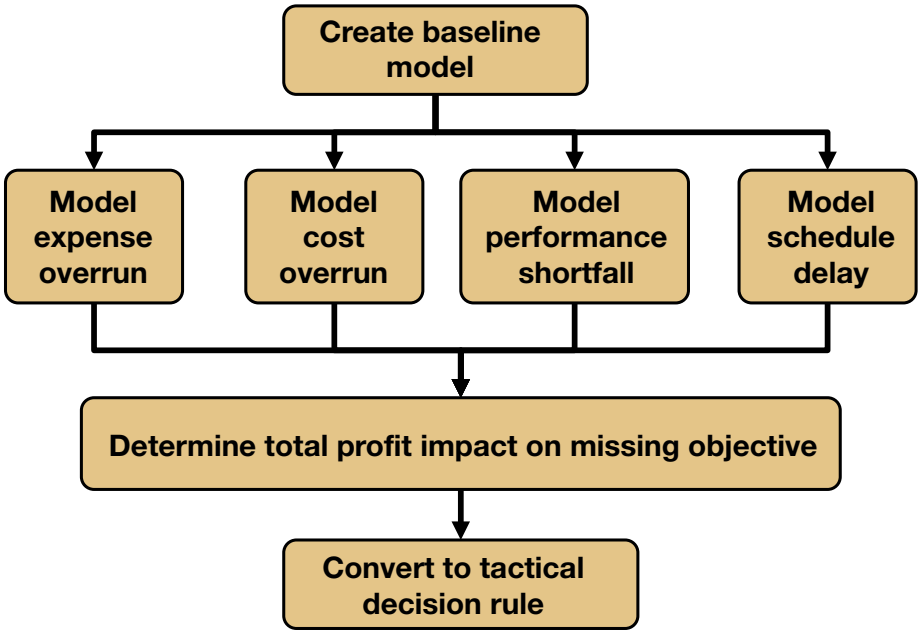
Figure 4-1: Economic modeling tool



One simple sensitivity analysis produced these tactical decision rules. They quantify the effect of a 1% change in expenses, project cost and performance shortfall as well as the effect of one month delay.

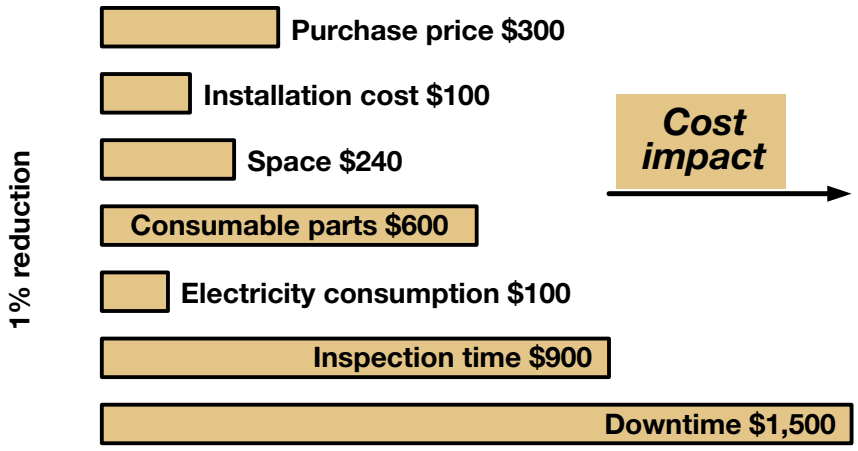
Source: Charts after D. Reinertsen, Machine Design, May 1998

Creating trade-off rules



Application trade-off rules

Life-cycle profit impact



An application economic model helps decide trade-offs among individual project features or attributes. The various economic drivers – installation cost or downtime – can be quantified and estimated, and total ownership cost expressed in dollars. This can be used to calculate the trade-off rules. In this case, reducing inspection time has 9x the impact of lowering electricity consumption.

Source: Charts after D. Reinertsen, Machine Design, May 1998

The economic modeling tool is based on setting uncomplicated trade-off rules in project development. It recognizes that every project has four key objectives:

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

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

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

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

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

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

A few tips on how to implement the economic modeling tool

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

It requires an effort to make some cultural change: turn away from intuitive decision-making and toward rational quantification. It's worth it.

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

4.4 DEVELOPING ENERGY MANAGEMENT PROGRAMS

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

- a first-year detailed project plan
- a medium-term energy saving plan for the entire brewery
- a long-term energy saving plan

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

- Plan to improve energy management in general, including the setting up of an energy monitoring system.

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

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

Setting priorities

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

Remember that without ongoing attention, the low-hanging fruit may grow back and the initial effort would be wasted.

44

Self-assessment provides a cue

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

5

IMPLEMENTING ENERGY EFFICIENCY OPPORTUNITIES

5.0 IMPLEMENTING ENERGY EFFICIENCY OPPORTUNITIES

5.1 EMPLOYEE INVOLVEMENT

The energy management program would achieve little without involving every one of the brewery's personnel, from managers to operators. The change of culture must involve all. Active participation and involvement of all employees in energy conservation measures and efficiency improvements are necessary.

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

Brainstorming sessions and suggestion programs may help tap into ideas, but they need to be held on a regular basis in order to yield the desired results. Some maintain that it is better to base these sessions on teamwork rather than on the initiative of individuals. This minimizes the potential of divisive personal rivalries.

Another solution is to approach energy efficiency as an opportunity for continual improvement, and use any of the number of proven techniques to achieve it, e.g. Quality Circles, Kaizen, Total Quality Management (TQM), etc. Of course, when a management system (as per ISO 9001, ISO 14001,

OHSAS 18001 or ISO 50001) is implemented, the continual improvement is already embedded in this standard as a key requirement for the entire organization. Energy efficiency improvement programs are often selected by the organization to realize its overall objectives and targets (see Section 4). In one such scenario, the team focuses on working on an identified need of the brewery.

Ongoing training also helps. Not every brewery can invest two hours of training per employee per week as would this Eastern Ontario brewery.

Case study: Training modules for middle management

A brewery decided that training all of their employees in recognizing energy waste and to reduce wastage was impractical. Hence, only middle management was chosen as they were able to influence energy usage, directly and by motivating their teams. A training course was designed with outside help (electric utilities, gas companies, NRCan) and delivered over extended lunch breaks.

It had four two-hour modules with one module per week at a cost of $150/person. The course first encouraged participants to carry out an energy audit of their homes and subsequently draw parallels to energy use at their workplace. Different approaches may work as well. They performed a walk-about energy audit of their own department and involved others.

Results: The effort resulted in a 3 percent reduction of the total energy bill, and a payback period of only three weeks. Before the project, only 10 percent of the workforce regularly took practical energy saving actions. After the project, that percentage increased to 85 percent.

5.2 EFFECTIVE COMMUNICATION

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

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

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

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

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

48

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

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

6

MANAGING ENERGY RESOURCES AND COSTS

6.0 MANAGING ENERGY RESOURCES AND COSTS

6.1 ENERGY AND UTILITIES COSTS AND MANAGEMENT

The brewery accountant could be the energy champion's best friend. All that has to be done is to explain to the accountant the concepts behind energy bills (see Section 7.2), and show him the energy implications of production non-quality on the total operational costs. Both fixed and variable costs may be affected.

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

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

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

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

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

Energy intensity, the cost of energy per hectolitre, electricity per work hour, and similar global measurements can be developed from these data. It is not always possible to separate the energy costs for heating and lighting of offices from the production part of the plant, or how much energy this or that process system uses. The basic information is not enough for an effective control: one needs to know ***how, where, when and why*** the energy is spent, and how much it costs. For instance, determining how much energy is wasted in a brewery during the non-production periods and on weekends may prove to be a revelation. This can be achieved, among other means, by sub-metering key equipment/operations. Other indicators may be developed:

- Energy (gas, oil or electricity) and cost of energy per hectolitre
- Average load factor
- Average power factor

- Boiler thermal conversion efficiency
- Brewhouse energy demand as a percentage of the energy demand of the whole brewery,
- Cost of electricity consumed by the compressors, etc.

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

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

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

Management tips	• Consider developing meaningful energy performance indicators specific to your brewery's needs. • Conduct seminars or awareness sessions for all operators to explain: 1. energy costs and the means of their control 2. effect of good housekeeping on driving the energy costs down 3. importance of proper operational practices • Review the indicators regularly at operations management meetings. • Keep employees informed – communicate the results. • Use the energy cost results in developing and reviewing of business plans, alternate energy plans and capital projects. • Use the energy cost indicators as a management tool to improve performance.

6.2 MONITORING, MEASURING CONSUMPTION AND SETTING TARGETS

This presumes the availability of data. It involves establishing a measurement base, to which the improvements can be related. Often, one quickly finds that there is only rudimentary measurement equipment installed (and consequently minimal data available), particularly in smaller breweries. This is a surmountable obstacle. An energy management program can still be implemented. As the program picks up steam and shows results, it will be much easier to convince management to invest in more metering equipment, gauges, sensors and controllers. These will allow data to be generated for key energy-consuming equipment.

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

52

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

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

Targets should be realistic, measurable and verifiable.

The brewery energy champion should manage the energy management plan as an ongoing program and coordinate a number of energy saving projects together. Consider interactions – beneficial or otherwise – between the various projects. You would not want to see one project's implementation negating the projected savings of another.

The best approach is to track consumption compared with a set target and past performance and react to aberrations with corrective and preventive actions, all in view of continual improvement. Performance analysis must take into account other accompanying factors, e.g. percentage of beer shrinkage, or production and process variations.

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

Selecting proper measurables	Monitoring and measuring consumption requires the careful selection of meaningful measurables that allow comparisons over time, using the same reference, e.g. kWh/hl of beer sold. The selection of the reference point is usually what causes some difficulties. Other base benchmarks could be selected, e.g. consumption of a given resource over hours worked, per employee, per hl of beer brewed (ex-brewhouse), per hl of beer in the government cellar, per $1,000 gross revenue, etc. However, these bases may change for a variety of reasons from year to year; the real improvement (or worsening) may therefore be hard to determine when the values of the bases shift. The ability to track performance over time requires a standard reference point.
Units of measure should not fluctuate over time	As in other business, breweries can chose the consumption figures related to the saleable product, i.e. to the hl of beer sold, as a measurement that is the most comprehensive, encompassing all influences in the brewery. That is valid for steady-state production make-up, relatively unchanging over long periods. When product make-up fluctuates at the dilution/carbonation volumes (i.e. brand volume sales), the brewery may wish to relate the consumption to a suitable production stage upstream (e.g. ex-brewhouse, ex-fermentation).

Set objectives and targets	Consider past performance, business and fiscal objectives, technology options and implications, in setting objectives in energy and utilities management. The objectives should be in line with the company policy (policies). Setting a target for appearance's sake would be counterproductive. A target should aim for continual improvement and be challenging – substantial yet achievable.
Visualize performance reporting	Graphical presentation of the tracked values (regardless of whether it is energy or productivity or overtime) should include at least the following parameters: average value for the past year, current target, current monthly performance and a trend line. The chart is a superb visual tool that conveys information powerfully and at a glance. The chart can be accompanied by a table, where actual figures and variations can be augmented by the expression of costs – all of these on year-to-date (YTD) basis.
Regular review	The performance of managing the consumption should be regularly reviewed (e.g. monthly), analyzed and reported at business management reviews.
Re-setting the target	Step by step target-setting helps managers regard energy as a resource that must be managed with equal attention as with other process inputs such as labour and raw materials.

6.3 ACTION PLANS – DEVELOPMENT, IMPLEMENTATION AND MONITORING

Action plans

For the energy champion, to be able to implement the energy management plan and the various EMOs, it will be necessary to work out specific action plans. These will give him the management and control tool needed to achieve targets effectively and efficiently. The plans will detail, who will do what, when, and with what resources. This process can only be meaningful and effective if it involves as broad a base of brewery employees at as many functions and levels as possible. Responsibilities, accountabilities, resources required and timelines should form a part of an action plan to reach the objectives and goals. The action plan should include the other energy management opportunities and tips found for every process under Section 7 – Technical and Process Considerations. Several project management software programs can be used to create the graphical representation of the action plans easily.

Start the work early

Do not procrastinate. Delays cause enthusiasm to wane. Begin with projects that are simple and will boost the team's confidence. Provide positive reinforcement that helps employees to willingly adopt new energy-saving practices.

Remember: A dollar saved goes directly to the bottom line.

54

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

Establish ongoing monitoring

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

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

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

Express the energy performance meaningfully

Express measurements in SI units such as MJ or GJ because they enable global comparisons. For example, state the energy consumption or savings as follows:

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

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

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

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

Lock in the gains – set new targets

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

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

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

6.4 MONITORING AND TARGETING (M&T)

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

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

Molson Coors Canada's brewery in Toronto-Etobicoke was the first to implement M&T in Canada, with rather spectacular results. These were published (*Energy Services, Case Study No. 1*, Ontario Hydro, December, 1994). According to the report, an initial $200,000 investment realized savings of about $1.5 million on water charges alone in the first year of implementation. Since then, other breweries in Canada have implemented M&T.

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 percent and 18 percent of fuel and electricity bills. Other intrinsic benefits lie in the beneficial change in the brewery culture such as 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.

Experience has shown that improvement in ordinary housekeeping practices (i.e. minding the energy consumption used every day such as switching off unneeded equipment, etc.) typically produces 10 to 15 percent savings. Achieving the percentages of profit margin increase with 35 percent energy savings, as shown in Table 6-1, is not at all improbable.

Table 6-1: Profit increase from energy savings

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

Table adapted after V.A. Munroe

The M&T system's implementation costs will depend on the extent of meters installed, the coverage desired and the methods used for recording and analyzing energy use. The 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 the division of the brewery into energy-accountable centres (EACs), those that convert energy and those that use it. An EAC should correspond to an existing management accounting centre such as the brewhouse. For obvious reasons, EACs should not

straddle different managers' jurisdictions. Within each EAC, energy consumption, e.g. use of steam, electricity, etc., is monitored. For additional control, energy might be monitored in specific areas within the EAC. For each item monitored such as boiler efficiency, a suitable index is needed against which to assess performance. For each index, performance standard needs to be derived from historical data that take into account the 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, managers whose consumption is targeted must agree that the targets are realistic. Table 6-2 lists a few possible measurable parameters (specific consumption figures).

Table 6-2: Deployment of M&T (example)

Brewery Process Areas	Measurement
Brewhouse	Consumption/hl cold wort
Fermenting	Consumption/hl cold wort
Cellars/beer processing	Consumption/hl bright beer
Packaging	Consumption/hl shippable beer
Energy centre	**Measurement**
Refrigeration	Consumption/GJ cooling
Steam production	Consumption/GJ heat
Air compressors	Consumption/Nm^3* air
CO_2 collection	Consumption/kg treated CO_2
Other functions	Consumption/week

* Normal cubic metre

Measuring brewery process areas requires the installation of meters at key points in the system, especially on 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 (Table 6-3) as a minimum:

Table 6-3: Installation of energy and utilities meters (example):

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

* 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 meters and associated monitoring equipment will soon be offset by the gains achieved following the implementation of an M&T program. It takes about 18 months from the initial decision to investigate the M&T potential to full implementation of the system.

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

7

TECHNICAL AND PROCESS CONSIDERATIONS

7.0 TECHNICAL AND PROCESS CONSIDERATIONS

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

This section describes what can be done with energy and water conservation in the brewery processes. **Energy efficiency improvement opportunities (EMOs) and tips are roughly categorized** – as pointed out in the introductory chapter – into three categories as shown below:

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

Medium costs (retrofit of equipment or buildings required; payback period of three years or less)

Capital cost (change in process, new plant or equipment required; payback period of three years or more). Generally speaking, these energy improvement opportunities can be expected to have the longest payback.

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

7.1 FUELS

This section and Section 7.3 on boiler plant systems are closely linked and should be read together.

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

The choice of fuel requires careful consideration. Factors such as the price of fuel, the capital cost of the plant, its current and anticipated future supply operating and maintenance costs, all have to be evaluated. As most of the boiler plants in Canadian breweries are aging, these considerations will come into play when deciding between retrofitting and replacing the plant. Table 7-1 may be of particular interest to brewing companies considering a start-up of new operations.

Table 7-1: Comparison of fuel types

Fuel Type	Advantages	Disadvantages
Natural gas	• the most convenient to use • readily available • no storage required • mixes readily with air • 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	• safety equipment maintenance required
Liquefied Petroleum Gas (LPG) (usually propane; sometimes butane)	• all the general comments about natural gas apply equally to LPG	• requires storage facilities (capital or leasing costs, operational and maintenance costs, inspections and testing of storage pressure vessels and delivery systems) • special precautions needed in relation to leakages • heavier than air • may seep into underground tunnels, ducts • requires forced dispersion with a fan (storage siting consideration) • LPG butane, although slightly cheaper, liquefies at 0°C • needs power source for evaporation at low temperatures

Heavy oil **Bunker oil No. 6**	• cheaper than lighter grades, sometimes cheaper than gas	• requires storage systems • capital and maintenance intensive • potential for leakage and soil/water contamination regular inspections required • due to high combustion temperatures, it produces oxides of nitrogen (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 • 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 0.1-0.3% sulfur content; • remains fluid to -11°C	• gels in extreme cold • waxes may precipitate in cold weather • may clog filters • requires heat tracing • other properties are similar to heavy oil

Other fuel considerations

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

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

In three Western provinces – the marketplace for natural gas – industry has long been competitive. Ontario and Quebec have also got used to the deregulated market conditions. Natural gas prices have risen sharply since 2000. Energy efficiency and demand side management (DSM) will be increasingly important tools for breweries to manage costs. Large users of natural gas are purchasing gas on the spot market and are using software to manage the task for maximum benefit. While

escalating gas costs are a major factor in energy budgets, at least one larger company has managed to offset them by installing combined heat and power (CHP) co-generators for generating their own electricity and selling a potential surplus to the distribution network. Others may follow suit when business conditions allow it.

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

Gas/oil delivery system

Is the system tight, without obstructions or leaks? Gas lines, many of which may be decades old and buried underground, may be corroded and may leak. To find out whether they are leaking, record the gas meter reading during a no-production period and again after a period of 12 to 24 hours. Provided the gas water heater was not on, there should be zero difference in the reading. Gas consumption for space heating, etc. can be accounted for by estimating the consumption based on the plate information. If leaks are detected, work should start on uncovering their source and fixing them promptly (safety may be involved). Similarly, check the tightness of the oil systems, which may produce less accurate results and require more time. If suspect, surrounding soil analysis may provide an answer.

In oil supply systems, ensure that filters are regularly checked, and pumps maintained.

Combustion

Very frequently, adequate controls are lacking for oil and gas furnaces. Poor control of air/gas ratio results in wasted energy, frequently excessive temperatures and wasted money. More on the topic can be found in Section 7.3.1 and 7.3.2.

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

Air-tightness of the boiler furnace chamber

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

Fuels: Other EMOs and tips

Note: Points of interest, particularly (but not exclusively) for small breweries, are shown in colour italics.

Housekeeping, no or low cost	• *Inspect gas/oil lines for corrosion and other sources of leaks to ensure no losses are occurring.* • *If underground oil tank or pipes are suspected of leakage, consider contracting for analysis of surrounding soil: it will cost you, but it may save much more by preventing much larger soil decontamination cost.* • *Inspect the aboveground fuel oil tank insulation and supply pipes insulation; repair it without delay.* • *The gas company can be approached with a request for a loan of extra gas meters for sub-metering major gas-burning equipment.* • *Avoid heating the entire oil storage tank to the required pumping (circulating) temperature. It is a wasteful practice. 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 percent of oil over the maximum demand of the burners. • *Ensure that electric heat tracing works and is used only when necessary.* • *If steam is used for tracing, evaluate the cost vis-à-vis electric tracing.* • *Subject gas suppliers to competitive bids.* • *If the boiler is dual fuel-fired, review your gas supply contract and consider an interruptible supply option that carries a lower gas price.*
Medium cost	• Consider installing gas flow meters to manage consumption of major gas using equipment such as boilers and water heaters. • Monitor and control the boiler furnace inside pressure. • *Consider using the local gas company as a contractor for maintenance services to your gas burners.* • *Your local oil supply company can help with efficiency testing and off-gas analyses.*

7.2 ELECTRICITY

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

Start by examining the components of the electricity bill in an effort to save electricity. Often these are not fully understood and consequently opportunities of potential savings are lost. A brewery can leverage this knowledge profitably in managing electricity use on site, and in negotiating with energy companies in the deregulated electricity market in Canada. When **conserving electricity, focus on where the potential savings are**.

The electricity bill – four possible components

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

   Ways to save:
   - Reduce the total electricity consumption (in kWh) in the facility
   - Shift energy consumption to times when energy costs are lower

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

   In breweries, there is excellent potential for cost savings from demand control and load shifting.

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

   Considerable savings are possible by simply managing the time when electricity is being used.

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

   - Reduce peak demand by
     - load-shedding (Figure 7-1), i.e. turning off non-essential electrical equipment
     - load-shifting (Figure 7-2), i.e. re-scheduling operations so that some activities take place during off-peak periods
     - process improvements, which reduce electrical power requirements
     - negotiating, if the utility allows it, for 60-minute demand-setting period, instead of the 15-minute option
   - Control demand by demand controllers – devices that reduce potential peaks and flatten out brewery demand. If you already have a demand controller, examine its function relative to a frequency of load factor peaks. Demand can be also controlled by staggering operations and using new-generation power packs, which can split the power among the user centres to control the demand effectively.

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

Figure 7-1: Load shedding

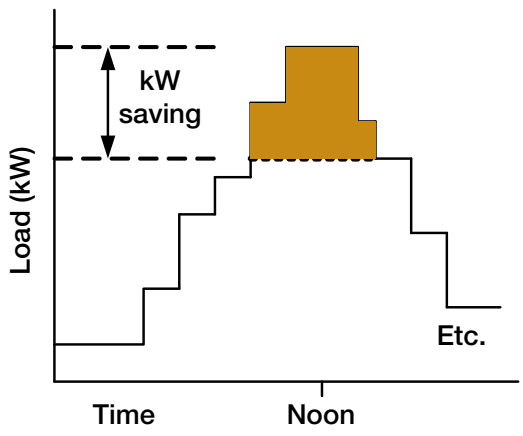
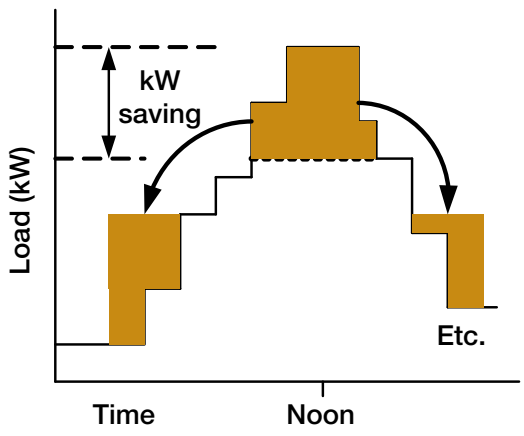


Figure 7-2: Load shifting



3. **Power factor charge:** It is the penalty charged by an electricity company to customers for poor utilization of power supplied. It is a measure of efficiency and is expressed as a ratio of the power passing through a circuit (apparently supplied in kVA) to actual power used (work performed, in kW). Utilities penalize customers having a power factor that is less than at a pre-determined level, usually 90 percent. Deregulation affected this.

   A power factor penalty is often obscured when the demand is billed in kVA, rather than the maximum kW level.

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

   A power factor may be improved by:

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

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

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

Ways to save:

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

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

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

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

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

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

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

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

Case study: Begin the practice of monitoring electric demand

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

Peaks in demand are caused by a number of factors, as discussed elsewhere in this Guide. The most important factors are starting large motors and 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 start up of the packaging line in the morning and timing use of other large power-using equipment to off-peak times.**

Solutions: 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 peak demand by nearly 100 percent. 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 = 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, in minutes
Tr = time remaining in the measurement period (T ΔT)

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 x (DC/kW-month) x AD where:
S = monthly savings, $/y
R = average demand reduction, %
DC = peak demand charge, $
AD = average demand

Results: 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 percent 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.

Electricity: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Involve all employees – the electricity conservation effort must be broad based and have the support of the operators. An awareness campaign should occur at the start.*
	• *Review the scheduling of brewery operations in view of the factors in the cost of electricity they consume.*
	• *Establish a baseline of power consumption during plant shutdowns, on Labour Day, Thanksgiving Day, etc., for energy use tracking.*
	• *Track and trend power consumption based on production and non-production days to spot the energy wasters. Then, develop procedures and shutdown checklists to ensure that equipment shutdowns are taking place.*
	• *Identify large consumers of electricity (e.g. refrigeration compressors, air compressors) and list them together with the related percentage of total electricity usage.*
	• Consider:
	  • *staggering the starts of the equipment with heavy power consumption or rescheduling 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 the case of large tanks full of chilled beer), etc.*
	• *Verify that motors are correctly sized for the job.*
	• Install automatic controls for shutting down equipment when not needed.
	• *Switch off all unneeded equipment (e.g. during lunch breaks, shift change and weekends).*
	• *Turn off unnecessary lights.*
	• *Consider installing photocell-driven switches and motion switches where feasible (packaging halls, corridors, cellars, warehouses, outside lighting, etc.).*
	• *Review motor burnout history and whether circuitries in the brewery need to be upgraded.*
	• *Maintain and calibrate automatic controls on all equipment.*
	• Control harmonic distortion passively and upstream; specify it in new equipment buying standards.
	• *Use the public utility as a resource: They can make suggestions as to demand reduction alternatives, points for metering, way of measuring consumption, possibly for the loan of a load analyzer, etc.*
	• *Request a load profile from your public utility company.*
	• Ask your public utility for advice on how to reduce consumption, reduce peak demand and improve power factor.
	• *Request from federal, provincial or municipal governments and the public utility, information on programs and financial incentives that may be available for equipment modifications and replacement.*

	• *To take the best advantage of tariffs, consider fitting a load analyzer to the brewery power supply to obtain a pattern of loading and major uses. Compare results with tariff rates and annual costs. Examine different possible scenarios for optimum results.* • *Consider conducting thermographic inspections of the brewery for heat losses, but also for detection of electrical hot spots, e.g. in a couplings and contacts, which indicate mechanical sources of losses.*

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

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

7.2.1 Alternate sources of electrical energy

The following are examples of the unconventional energy sources that are gaining recognition worldwide. It is a non-exhaustive listing as a detailed enumeration on those modes would be beyond the scope of this Guide. Specific technologies for tapping into these alternative energy sources, i.e. wind, solar, geothermal, fuel cells, biogas and biomass, although fledgling in most cases, have already proved their viability. It is an emerging trend that is pursuant to governmental directives worldwide to wean industries, in part, from conventional energy sources to renewables.

Considering them is not necessarily a domain of only the "big" breweries. A small Canadian brewer is already weighing its options for installing **solar electricity** panels and **geothermal** pumps.

Alternate energy sources are already used by Sierra Nevada Brewing Company (SNBC), a small brewery in the United States. Although the conditions and climate may be different, Canadian breweries can learn from them. Follows a verbal communication dated May 2010:

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

Heat recovery

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

Other efficiencies

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

Monitoring

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

Solar

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

- The parking structure array was commissioned in September, 2007. It consists of 2288, 225-watt SunPower panels and has a potential electricity output of 503 kW DC. This system is equipped with a sun tracking mechanism which follows the movements of the sun across the sky, adding 30 percent efficiency over a stationary system.
- The roof top array was commissioned in December 2008 and includes 7688 185-watt Mitsubishi panels. The system is capable of providing an additional 1.42 megawatts of DC electricity to the facility.
- SNBC has 28 panels on the company's daycare which offset the majority of electrical needs to run the center. There is also a 14 kW system that includes 76 panels installed on SNBC's rail transfer facility.

Fuel cells

In 2005, Sierra Nevada was the first brewing operation in the world to install hydrogen fuel cells. The onsite facility consists of four 300-kW fuel cell energy units that, together, are capable of generating 1.2 megawatts of electricity. The fuel cells run on natural gas and have the potential to be more closed looped by running on biogas generated at the Sierra Nevada waste water treatment facility. Sending the biogas to the fuel cells is currently a work in progress. The fuel cell installation provides roughly 60 percent of the total electrical needs for the facility and is made 15 percent more efficient with the installation of steam generating heat recovery units on each cell.

Biogas

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

SNBC is no longer alone. Another brewery, New Belgium Brewing Company of Ft. Collins, Colorado, has also embraced green technologies to secure their energy needs.

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

7.3 BOILER PLANT SYSTEMS

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 2133 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 3000 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 their advantage. Boiler design, maintenance and retrofit are specialized skills best left to expert from reputable suppliers. Their advice should also be sought when contemplating engineering or operational changes to a system.

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

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

7.3.1 Boiler efficiency

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

There is a fine line between the combustion efficiency and safety in ensuring that only the minimum excess air is supplied to the burner. Theoretically in combustion, the molecule of fuel is completely broken down to produce CO_2 and water vapour. In practice, to ensure complete fuel combustion, even the modern, well equipped combustion equipment must operate with excess air. Excess air has a beneficial effect in speeding up the mixing of fuel and air and provides all fuel with the oxygen necessary for combustion. It also prevents situations where incompletely burned fuel would create potentially explosive conditions within the boiler. Conversely, excess air wastes energy by carrying heat off up the stack.

A simple and direct method for calculating boiler efficiency:

1. Measure steam flow (lb. or kg) over a set period, e.g. one hour. Use steam readings integrator, if available.
2. Measure the flow of fuel over the same period, using the gas or oil integrator, or by determining the mass of solid fuel used.
3. Convert both steam and fuel to identical energy units, e.g. BTU or kJ.
4. Calculate the efficiency, using the equation: Efficiency = (steam energy: fuel energy) x 100

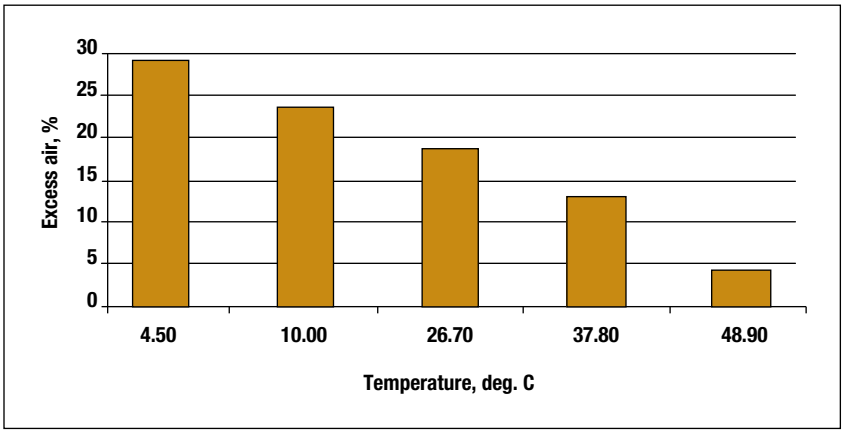
As our objective is to increase boiler efficiency, it will be useful to review some of the main causes of heat loss in boiler operations.

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

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

It is important to realize that air-to-fuel ratio is a mass ratio, not a volume ratio. To control it means to control it on the basis of kg to kg. The burner controls should compensate for seasonal temperature variations, and optimally, for day/night variations as well. Sophisticated systems also compensate for air pressure. The effect of air temperature on excess air in flue gas can be dramatic as shown in Figure 7-3 below.

Figure 7-3: Effect of air temperature on excess air level



Typically, a 1-percent O_2 reduction corresponds to a 2.5-percent efficiency gain. Control of excess air is the most important tool at an operator's disposal to manage the energy efficiency and atmospheric emissions of a boiler system.

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

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

Another way to control blowdown heat loss 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. Blowdown control may be done by opening a valve manually for a period of time at certain intervals (based on experience or on boiler water analysis) or continually, by an automatic timer-operated valve, or automatically, based on monitoring of TDS by a conductivity meter. Obviously, the latter method, with adequate safeguards, will minimize blowdown heat loss.

An example of what a poorly managed blowdown can cost:

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

7.3.2 Environmental impacts of boiler combustion

The environmental impacts of boiler combustion are worth mentioning briefly here. It is also mentioned in Section 7.1 under Combustion and examined in detail in NRCan's guidebook "*Boilers and Heaters – Improving Energy Efficiency.*"

The brewery's boilerhouse faces a double challenge: one economic – getting the best possible value out of its fuel budget, and the other environmental – keeping emissions as low as possible, to stay well within the legislated limits. Fortunately, the two objectives are interlinked. The Canadian Council of Ministers of the Environment (CCME) published NO_x emission guidelines for new boilers and heaters, see Table 7-2 below.

The guideline provides higher limits for equipment that can be shown to be highly efficient, therefore burn less fuel. Enforcement of the guideline is a provincial responsibility and provinces may enact stricter limits. Read the CCME Guideline to find out how it applies to a boiler undergoing modifications or a boiler overhaul. It is rather important to know what is involved when the brewery has older equipment. The strategies for achieving compliance with NO_x regulations, which are beyond the scope of this Guide, can be found in NRCan's "*Boilers and Heaters – Improving Energy Efficiency*" at oee.nrcan.gc.ca/Publications/infosource/Pub/cipec/BoilersHeaters_foreword.cfm or at www.energysolutionscenter.org/boilerburner/Primer/PrimerFrameSet.htm).

Table 7-2 shows the CCME NO_x emission guidelines for new boilers and heaters and Table 7-3 shows typical NO_x emissions without NO_x control equipment in place.

Table 7-2: CCME* NO_x emission guidelines for new boilers and heaters

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

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

To correct ppm NO_x to 3% O_2:	NO_x at 3% O_2 = (NO_x measured x 17.9) : (20.9 –O_2) where O_2 is oxygen measured in flue gas, dry basis
To convert ppm NO_x at 3% O_2 to g/GJ:	For natural gas, g/GJ = ppm: 1.907 For fuel oil, g/GJ = ppm: 1.808

Table 7-3: Typical NO_x emissions without NO_x control equipment in place

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

Heat recovery in the boilerhouse

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

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

Case study: Preheat boiler combustion air with stack waste heat

A 300-HP natural gas boiler was drawing air from the outside, which resulted in unnecessary fuel consumption to heat the combustion air. The boiler used 56 787 Therm per year and was operating at 82 percent efficiency. A high-quality heat recuperator could recover up to 60 percent of waste heat, or 6133 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 x (1 – η) x RC; where
CS = cost savings, $/y
EC = energy consumed, Therm/y
η = boiler efficiency, %
RC = energy recoverable by recuperator, %

Results: The installed cost of the recuperator was $19,980 (at the time), and the simple payback period was 3.4 years. However, the payback period could be reduced significantly if the operating time increased through larger production and more shifts.

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

The same 300-HP boiler used, as an example in the case study above, excess combustion air that showed 6.2 percent oxygen in the flue gas and a temperature of 204°C. Optimally, the excess oxygen should read only 2 percent, which corresponds to 10 percent excess air. This could provide a possible fuel saving of 3 percent.

Results: Using data from the above case study and a chart plotting excess air (%), stack temperature, fuel savings (%) and % O_2 versus excess air, it is possible to calculate the savings. Savings would amount to $1,083 annually (at the time). With a $750 purchase of a flue gas analyzer, the simple payback was 8.2 months.

Boiler efficiency: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Keep your boiler clean. Remove deposits on the fireside of the tubes. This fouling reduces heat transfer dramatically: a mere 0.8 mm thick soot layer reduces heat transfer by 9.5 percent and a 4.5 mm layer by 65 percent. The flue gas temperature rises as a result and so does the energy cost due to energy losses.* • *Maintain the soot removal mechanisms in good condition (e.g. soot blower systems, brushes, manual lances, etc.).* • *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 percent.* • *Analyze the boiler water regularly to verify effective water treatment and prevention of scale depositing.* • *Keep unwanted air out. Set up the boiler to achieve optimum combustion efficiency (air/fuel ratio). An insufficient fuel ratio will result in soot formation, decreasing heat transfer on the fireside of the boiler (if oil is used).* • *Prevent ingress of extra air to the combustion chamber.* • *Check boiler efficiency regularly and maintain records. (A simple calculation involves converting the amount of fuel used in a given period and steam generated to energy units [kJ or Btu]. Boiler efficiency will be the ratio of the two.)*

- *Check flue gas oxygen and carbon monoxide levels regularly with a manual (Chemical Orsat) or automatic flue gas analyzer. The oxygen levels should be in the following ranges:*
  - *Natural gas: 2.0 percent min. and 2.7 percent max.*
  - *Heavy fuel oil: 3.3 percent min. and 4.2 percent max.*
  - *Light oil: 2.3 percent min. and 3.5 percent max.*
  - *(Note: The above settings are typical for boilers without low excess air combustion equipment. In the case of natural gas, a 1.7 percent minimum value can be achieved).*
- *Remember that a 10-percent reduction in excess oxygen will reduce flue gas temperature by 2.5 percent and increase boiler efficiency by 1.5 percent.*
- *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.*
- *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 day of the week and seasons.*
- *Maintain control settings to prevent overheating.*
- *Maintain steam pressure to suit demand and avoid excess pressure.*
- *Attempt to stabilize heating demands by reviewing process demand scheduling so as to minimize boiler load swings and to maximize boiler efficiencies. Attempt to maintain full-load boiler operation.*
- *Avoid dynamic operation. Review brewhouse kettle boil control and steam valve operation.*
- *Lower the steam pressure (or water temperature) to what is actually required by processes – suit the supply to the demand and do not oversupply (e.g. if no pasteurization is going on, scale down the steam pressure to only the brewhouse requirements).*
- *Choose a low-pressure operation during non-production periods or deploy a smaller boiler only.*
- *Compress the brewing schedule in the low production periods to avoid stops and starts of large boilers.*
- *In summer, block the boilers in by closing king valves: No heating is required and no steam is distributed, but keeping the boilers hot will considerably increase the life of firebrick lining and tubes.*
- *Ensure proper de-aeration of boiler feedwater by checking and maintaining air vents.*
- *Regularly calibrate measuring equipment and instrumentation, and tune up the combustion control system.*
- *Regularly check all the control settings.*
- *Regularly check and verify boiler efficiency.*
- *Regularly monitor and compare boiler performance-related data to standards and targets.*
- *Regularly apply routine and preventive predictive maintenance programs to the boiler and heat distribution/ condensate collection systems.*
- *Review whether there are combustible by-products available inside or in the vicinity of your brewery (e.g. biogas from your anaerobic WWTP, waste hydrogen, oxygen, carbon monoxide [CO] or hydrocarbon streams from a nearby factory) that you could utilize as no-cost or low-cost boiler fuel supplements.*

Medium cost	• Collect blowdown to generate low-pressure steam for use in heating systems or for deaerators. Use other heat to preheat make-up water. • Consider fitting boilers with burners that will mix waste oil with regular boiler fuel to gain additional energy and reduce disposal costs. • Add/upgrade measuring, metering and monitoring equipment to the boiler and heat distribution systems, e.g. for fuel, steam, heating fluid, condensate and blowdown flows. • Optimize the location of sensors: Ensure that sensors and control devices are easily accessible for control and maintenance. • Fit controls with locks, to prevent tampering and unauthorized adjustments. • Relocate the combustion air intake to a location where the incoming air has the highest possible temperature year round.
Capital cost	• Consider instituting a metering and targeting (M&T) program to manage better the thermal energy usage throughout the brewery. • Consider the economics and means of capturing radiation and convection heat from the boiler shell for combustion air pre-heating. Evaluate the flue gas heat recovery system for feedwater preheating 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 percent.*** • Consider installing the latest types of heat-reclamation equipment; economizers and air heaters for flue gas and heat exchangers/heat pumps for boiler blowdown. • ***Consider deploying a heat cascading principle in the brewery, and, if possible, where high-grade heat supplied from fuel is directed to the brewhouse (the process having the highest temperature requirement) and where the exhaust heat is used in lower temperature applications (e.g. in the bottle washer).*** • Consider investing in high-precision burner controls for continuous correct air-fuel ratio management. • Upgrade the fuel burner: For example, consider employing the fuel direct injection (FDI) technology. A full-time FDI regenerative burner (FFR) reduces NO_x emissions by about 90 percent compared to ordinary regenerative burners. The compact FFR burner allows simplifications and downsizing, along with significant energy consumption reduction and a short payback period. • Install a turbulator in the fire-tube boiler. • Install local high-efficiency boilers that respond rapidly to load demands. • Consider removing heat sinks when switching off boilers is necessary: If dense firebrick is used for lining the furnace, it needs to be installed in adequate thickness to limit the heat conductive losses. However, the large mass of the firebrick acts as a heat sink and is expensive to heat up. New low-density ceramic fibre materials are used, often in combination with other refractory materials, to remove these heat sinks and provide superior thermal insulation. • Consider repositioning upgraded burners in the boiler furnace. A company in Quebec did this. It improved furnace heat distribution and achieved natural gas savings at the same time.

7.4 STEAM AND CONDENSATE SYSTEMS

This section is linked to the description of boiler systems in Section 7.3. They should be read together.

Remember: Loss of steam or loss of condensate equals money down the drain.

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

Optimum steam pressure	In a balance between capital cost and the overall efficiency of the system, steam pressure should meet the maximum efficiency 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. The steam distribution system should be reviewed every few years for adequacy in light of changes in the brewery such as future expansion plans, 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, existing but unused piping is seldom removed. The first step in any review of pipework is to remove redundant piping and 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 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 the thickness of the insulation results in 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 a case study in Section 7.17 Maintenance.

Leakage

(See Section 7.17 Maintenance)

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

The table below shows how much it may cost when typical leaks in a 7-bar(g) system are related to the fuel wasted. The cost of several leaks can be easily assessed by using the current rate the brewery pays for fuel.

Table 7-4: Steam leakage losses

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

Heat transfer

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

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

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

Insidious and 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 concern if poorly selected, installed or maintained. Steam and condensate may be lost through steam traps. Condensate and air that is inadequately removed from the steam pipes and equipment reduces efficiency.

Condensate recovery

Loss of condensate is literally like throwing money down the drain. If not returned to the boiler, about 20 percent 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 and its heating. Additional energy losses occur in the form of flash steam that develops when the process pressure, under which the condensate is returned, is released in the condensate return tank. This is called open condensate return system.

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

Steam and condensate systems: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• ***Examine current plant piping drawings, if available, or walk through the facility and look for opportunities to rationalize and streamline the steam and condensate network. First, ensure that obsolete, unused or redundant piping can be isolated from the rest of the system. Then plan on removing the parts that are no longer required.*** • *Ensure the efficient operation of process equipment, which uses downstream steam and hot water, by proper production scheduling and maintenance.* • *Attempt to operate the downstream steam and hot water by using equipment at capacity.* • *Shut the downstream steam or hot water using equipment when not needed.* • *Shut the downstream steam and condensate branch system when not needed.* • *Maintain good steam quality: Maintain the program of regular water chemical treatment, blowdown regime and ensure proper function of feedwater de-aerating equipment and air vents on steam piping.* • *Repair, replace or add air vents (e.g. thermostatic air vents).* • *Regularly check the integrity of the steam and condensate network (heating fluid supply and return network) and associated equipment. Walk through the facility with appropriate detection equipment (e.g. ultrasonic detector, listening rods, pyrometer, and stethoscope) and look for and listen for steam leaks.* • *Identify and repair steam and condensate leaks.* • *Properly insulate steam and condensate return lines and components with efficient insulation at an economic thickness.* • Add insulation where it is inadequate. • *Inspect the insulation for waterlogging; locate the source of the moisture and correct the problem (e.g. leaking pipe).* • *Replace or repair any missing and damaged insulation and/or isolation covering.* • *Set up a steam trap maintenance program to ensure optimum performance, and reduce downtime of steam systems.* • *Review whether the steam and steam condensate recovery network (and heating coils and other steam using equipment) has proper drainage; eliminate water hammer, and losses and damage that it generates.*

Medium cost	• Consider flash steam recovery 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. • Suggestion contributed by a brewer: Consider the separation of process and heating steam and condensate return systems so that heating loops can be isolated during non-heating periods. • Consider using steam-powered condensate return pumps instead of electrically powered ones. • Collect all possible condensate (this should be as close to 90 percent as possible, or better). • Decommission redundant steam and condensate return piping. • Shorten and/or simplify the existing steam and condensate return piping. • Overhaul steam pressure-reducing stations. • Institute a steam trap replacement program. • Replace incorrectly selected steam traps with the correct type for the service.
Capital cost	• If used in pasteurizers and soakers, consider replacing live steam injection that loses the condensate from circulation, i.e. consumes de-mineralized make-up water and necessitates its heating and conversion into steam and dilutes the caustic concentration in soaker baths, with heat exchangers. • Consider installing a closed-loop pressurized condensate return system. • Have a qualified contractor review, and if necessary, redesign the steam and condensate network to optimize it. Re-pipe systems or relocate equipment to shorten pipe lengths where it makes sense.

7.5 INSULATION

The key step: Determine the economic thickness of insulation. It is the thickness that provides the highest insulation for the lowest cost.

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

We insulate process equipment, ducts, piping and buildings to

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

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

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

Base the choice of insulation material on the following criteria:

- ***Halocarbon-free***
- ***Flammability/resilience***
- ***Performance/price***

Water-saturated insulation transfers heat 15 to 20 times faster than when dry.

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

See insulation mentioned under Section 7.17 Maintenance.

Insulation: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Inspect the condition of process insulation regularly (include it in the afternoon or evening schedule).* • *Repair damaged insulation on pipes and vessels with cold or hot media, without delay.*
Medium cost	• *Insulate non-insulated pipe and ductwork.* • *Insulate non-insulated equipment.* • Upgrade existing insulation levels; add insulation to reach recommended thickness. • Insulate major non-insulated equipment/process areas. • Hire a thermography consultant to discover areas in need of (additional) insulation or air leakage control. • Improve insulation of hot water tanks.

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

7.6 REFRIGERATION, COOLING SYSTEMS AND HEAT PUMPS

7.6.1 Refrigeration and cooling systems

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

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

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

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

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

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

Savings opportunities arise from effectively controlling 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 includes power to all the auxiliary equipment such as evaporator fans and pumps, condenser fans and pumps, oil pumps, secondary refrigerant distribution pumps and fans and defrost heaters.

Factors affecting refrigeration efficiency include:

Cooling loads

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

Compressor efficiency

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

Evaporating temperature

Raising the evaporating temperature increases COP and lowers the running costs: raising the evaporating temperature by 1°C reduces costs by 2 to 4 percent. Higher evaporating temperatures can be achieved by good controls and taking 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 percent. Lower condensing temperatures can be achieved by good controls and taking care of the evaporating surfaces (avoidance of fouling, superheating, blockages and poor heat transfer). See the brewer-contributed note on incondensables under Section 9.5.

Auxiliary power

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

As pointed out above, cooling loads should be kept to a minimum. Brewers should 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)
- 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, 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 percent.
- A 1°C reduction in evaporating temperature will increase costs by 2 to 4 percent.
- Gas by-passing expansion valves may add 30 percent or more to your costs.
- Incorrect control of compressors may increase costs 20 percent or more.
- Poor control of auxiliary equipment can increase costs by 20 percent or more.
- Both gains and losses are cumulative.

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

Case study: Refrigeration fault diagnosis system

A one million hectolitre-per year brewery capitalized on resident expertise and, with the aid of a consulting firm, developed and installed a Refrigeration Fault Diagnosis Expert System to evaluate refrigeration plant status and to advise on appropriate remedial action when there is a fault. An investment of $36,000 for the purchase of a computer, software development and customization, and

operator training (dated costs) produced savings that allowed the brewery to recoup its investment in eight months during the training phase alone.

Results: Several of the system's modules monitor key measurements and data, calculate coefficient of performances (COP) and analyze faults. Given the ambient temperature, they recommend preferred actions for establishing the best combination of cooling equipment packages and loads to meet the current cooling duty. This resulted in a reduction in electricity consumption by 29.5 percent and savings.

The following three case studies were recently contributed by breweries that experienced various energy inefficiencies at their plant and made recommendations to resolve the issues.

Case study: Installing a new primary compressor (brewer-contributed study)

A brewery has two 125-HP reciprocating, one 450-HP screw, and one 700-HP screw ammonia compressors. During two summer months of monitoring, one of the two screws operated at all times with one reciprocating compressor supplementing the other.

These existing Mycom screw compressors had four major inefficiencies:

- The compressors are equipped with a 3.6 internal compression volume ratio (VI). This ratio is mismatched to the average operating conditions, which call for a lower ratio. The compressors overcompress most of the time, reducing efficiency.
- The compressors utilize standard slide valve capacity control, which is inefficient. When fully unloaded, the compressors still draw nearly 50 percent input power. This poor part load performance reduces efficiency.
- There is some question as to the minimum allowable discharge pressure at which the screw compressors can operate. The Mycom rating software indicates a minimum of around 120 psig. Lubrication or oil separator performance is often the limitation. This elevated discharge pressure reduces efficiency.
- The 450-HP TECO motor is rated at 94.0 percent efficiency, while the 700-HP Toshiba is rated at 95 percent efficiency. If they have been rebuilt, it is feasible that current efficiencies are even lower. Efficiencies over 96 percent are available for modern premium motors.

Recommendation: the installation of a new primary compressor package to minimize or eliminate these inefficiencies. The new compressor should have

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

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

Case study: Evaporator fan cycling or two-speed control (brewer-contributed study)

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

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

Case study: Implement VFD strategies on condenser fans (brewer-contributed study)

Currently, one of four evaporative condensers utilizes VFD control. Although this provides some savings, the mix of discrete (cycling) and analog (speed) control makes for challenging control algorithms. A staggered condenser strategy stages capacity from 120 psig up to 150 psig. The strategy turns fans on before pumps, resulting in stages of dry condenser operation. This is extremely inefficient.

Recommendations: This measure includes several major upgrades:

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

7.6.2 Industrial heat pumps

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

Case study: Waste heat recovery with a heat pump

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

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

Refrigeration, cooling systems and heat pumps: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• Also refer to Section 7.2.1. • *Operators may not understand refrigeration efficiency issues; educate and train them first.* • *Operation and maintenance issues need to be constantly addressed; an inefficient operating mode may be more convenient to the operator.* • *Review your refrigeration plant regimen frequently as process requirements and ambient weather conditions change.* • *Implement good housekeeping practices.* • *Keep the doors to refrigerated areas closed.* • *Separate the cold areas from the rest of the brewery by installing doors, plastic curtains, rubber swing doors, etc.* • *In refrigerated rooms, use as little water as possible. Remember that one gallon of water needs a ton of refrigeration of energy to evaporate. Channel tank, flushings, etc. directly to the drain; do not let them spill onto the floor, where they would have to be hosed down.* • *Eliminate ingress of moisture into the cooled space (from ambient air and from water hoses).* • *Use cold cleaning-in-place (CIP) in refrigerated rooms whenever possible. Talk to your cleaning materials supplier about a suitable cleaner.* • *Review electric power tariffs and schedule running the refrigeration plant to avoid adding to the peak demand periods or set maximum cooling duties for night time.* • *Ensure controls for defrosting are set properly and review the setting frequently, for example, monthly, to take account of changing ambient conditions.* • *Ensure that defrosting operates only when necessary and for as short a period as necessary.* • *Review your system controls and correctly set points for evaporating and condensing temperatures.* • *Regularly measure the compressor COP and the overall SCOP, which includes auxiliary equipment to control the operation.* • If water for condensers is supplied from cooling towers, ensure they are effectively maintained (fans, pumps, fouling, etc.) to obtain the lowest water temperature possible. • *Check buildup of non-condensable gases and air on a regular basis to ensure the plant operates at high COP.* • *Check for the correct head pressure control settings.* • *Check for the correct levels of refrigerant in the system for optimum performance; eliminate leaks.* • *Suggestion contributed by a brewer: Consider implementing an oil inventory management program to track the amount of oil added and drained from the system.* • *Suggestion contributed by a brewer: Try to ensure that pressure drop across the oil separator does not exceed 4 psi; anything above that indicates oil carryover.* • *Adjust the cooling plant's evaporation temperature to about -6°C to 8°C, or 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, for example, 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. • A regular testing program should be established so problems are quickly identified. • *Review your maintenance program to avoid fouling, flow blockages and to ensure good maintenance of pumps, fans and lights, etc.*

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

Capital cost	• Replace compressors with the most efficient type available, when justified. • If a number of evaporators in an integrated system are operating at pressures considerably higher than the suction line pressure, consider installing a separate system to enable running a portion of the load at higher operational suction line pressure and, therefore, higher COP (dual pressure ammonia system). • Consider thermal storage, i.e. coolant storage (using ice tanks, eutectic salts or supercooled secondary refrigerant) to maximize the use of night-rate power. This will also reduce the requirement for additional chiller capacity if increased cooling demand is needed. • Evaluate the utilization of ammonia de-superheating heat recovery for preheating and reducing the cost of cooling in the condenser or cooling tower. • Evaluate absorption cooling if excess heat is available. This technology provides refrigeration without electricity input.

- Evaluate installing a combustion engine-driven chiller unit as it provides a less expensive energy input and has better part-load efficiency than electrical motors, besides affording 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.

7.7 COMPRESSED AIR

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

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

Most brewery employees view compressed air almost as a free and convenient resource and are not aware that compressed air is the most expensive utility in the plant. Compressed air is an inefficient medium as some 85 percent 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 percent 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 percent 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 percent 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. Table 7-5 illustrates the results of leakages through holes of various diameters in a 600 kPa g system, using electricity at $0.07 per kWh.

Table 7-5: Cost of compressed air leaks

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

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

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

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

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

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

On average, savings may be achieved by fixing:

- leaks (25 percent)
- poor applications (20 percent)
- air lost in drainage systems (5 percent)
- artificial demand (15 percent)

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

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

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

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

Simple, cost-effective measures can save 30 to 50 percent of generating electricity costs.

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

- analyzing demand and matching capacity to demand
- controlling peak demand events
- correcting poor applications and waste in using compressed air
- identifying and correcting leaks
- controlling and managing the entire system
- optimizing the maintenance program
- making users aware about correct practices and savings opportunities
- monitoring results, performance and costs of the compressed air system's operations

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

Analyze the demand	• Identify critical users and analyze their needs regarding compressed air pressure, volumetric flow, frequency of use and duration of the usage events. That will help in designing eventually custom-fitted solutions, and minimize affecting other users in the system ($).
Control peak demand	• Provide adequate compressed air storage capacity to reduce cycling; consider installing additional compressed air tanks ($). • Consider replacing part of the air distribution network with large-diameter piping to stabilize air supply and enable reduction of air pressure ($$-$$$).
Correct poor applications	• Replace vacuum generators using compressed air, pneumatic motors, dusting by blowing compressed air, and open blowing, with other equipment giving the same results but at lower costs ($-$$). If need be, install a low-pressure blower for the job.
Eliminate waste	• Generate compressed air at the lowest possible pressure suitable for the task ($). • Never generate at too high a pressure only to reduce it to a lower operating pressure later ($). • Do not compensate with higher pressure for poorly maintained air tools or undersized air distribution lines ($). • Consider using high-efficiency blow nozzles (reducing air consumption by at least 50 percent) ($). • Consider using a different nozzle type and configuration when blowing off water after pasteurization ($-$$). • Minimize losses of compressed air in various pieces of measuring and controlling equipment using it, install section valves ($$). • Consider dual pressure control for off-shift operation ($$). • Switch off compressors when not needed ($). Include the weekends, if possible.
Eliminate leaks ***Remember: A leakage reduction program must be ongoing to be effective.***	• Think of compressed air as you would water, stop the leaks at once ($). • Use the listening method after normal working hours ($). • Invest in an ultrasound listening device to identify leaks (e.g. Ultraprobe 2000™) ($). • Consider purchasing a compressed air leak tester to detect pressure drops because of leaks and to measure the compressor capacity ($$). • Consider implementing an automatic leak-measuring process, to be done on weekends, through a computerized control, regulator and monitoring system and installation of enough section valves.

Manage system	• Require users to justify using the compressed air ($). • Institute metering of the usage by end-point users ($). • Make users fiscally accountable for the compressed air usage ($). • Consider installing "load shaping" – a dedicated demand management system to handle peaks without affecting the pressure levels, starting additional compressors needlessly, or leaving excess compressors running "just in case" ($$$). • Use the central control, regulation and monitoring system to start/stop the compressors at pre-determined times during the week ($$$). (Note: One such program is the XCEED™ Compressed Air Management System.) • Uncontrolled compressed air quality can lead to production downtime. Implement a regular maintenance, inspection and preventive maintenance program for the system's components. In the program, also include the control and monitoring equipment ($).
Train operators	• In order to achieve operational savings and quality improvements, users and operators must understand the system and be aware of its operating costs ($). • Delegate responsibility to ensure that the compressed air system has no leaks ($). • Request operators to mark leaks manually as soon as discovered for maintenance to fix ($).

Monitor performance	• Install both electricity and air flow meters (vortex), to allow energy monitoring ($$).
	• Monitor the following parameters on a monthly basis:
	  • kWh/total number of labour hours in production
	  • kWh/m^3 (i.e. compressor efficiency)
	  • m^3/total number of labour hours in production
	• In addition, do likewise in terms of dollar costs.

Case study: Lower 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 percent.

Recommendation: 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 : η) x LF x H x S x WHP x CF; where
CS = anticipated cost savings for the compressor, $/y
HP = (nominal) horsepower of the compressor (i.e. 60 HP)
η = efficiency of the electric motor driving the compressor, %
S = estimated horsepower reduction (i.e. 7.5 percent)
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

Results: The simple payback period on savings of $480 per year (at the time) was immediate.

Case study: Repair 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 non-production. The total loss was 137 kg air/h. The mass flow out of a hole is calculated using Fliegner's formula:

$m = 1915.2 \times k \times A \times P \times (T + 460)^{-0.5}$; where
m = mass flow rate
k = nozzle coefficient (e.g. 0.65)
A = area of the hole
P = pressure in the line at the hole
T = temperature of the air in the line

Savings are calculated using the formula:

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

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

Case study: Redirect 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 percent.

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

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

CS = HP x (1 : η) x LF x H x WHP x CF x WR; where
CS = anticipated cost savings, $/y
HP = horsepower for the operating compressor, HP
η = efficiency of the compressor motor, %
LF = average partial load factor (e.g. 0.6)
H = annual operating time, h
WHP = conversion factor, 0.7459 kW/HP
CF = electricity consumption cost, $/kWh

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

Compressed air: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Maintain air filters.* • *Eliminate redundant couplings and hoses as potential sources of leaks.* • *Remove obsolete compressed air distribution piping (to reduce pressure loss, leaks and maintenance costs).* • *When reciprocating and screw compressors are used in parallel, always maintain screw compressors at full load. When partial loads are required, shut down the screw compressor and use the reciprocating compressor instead.* • *Avoid using compressed air when low-pressure blower air will do the job* • *Ensure the system is dry. Ensure that drainage slopes, drainage points and take-off points (always on top) prevent internal corrosion of the piping.* • *Review all operations where compressed air power is being used and develop a list of alternative ways.* • *Review the compressed air system and air uses annually. Simplify the task by developing a checklist.* • *Keep all air tools, connectors, and hoses in good repair.* • *Commit to a brewery-wide awareness program.* • *Draw intake air for both compressing and compressor cooling (if air-cooled) from the coolest location outside, probably by direct ducting of fresh intake air from the outside.*

	• In air-cooled compressors, discharge heated air outdoors during the summer and use indoors for space heating during winter. *• Check that the system being operated is not faulty (if it requires higher than design pressure).* *• Check that there are no problems with piping causing system pressure drops.* *• Ensure that the system is dry: correct slopes of the piping, drainage points, and take-off points (always on top of piping).* *• Beware of piping corrosion; it can lead to pitting and leaks.* *• Implement a regular system maintenance and inspection program.* *• Invest in a leak detector/air leak tester to measure total volumetric leakage throughout the compressed air system and also the compressor capacity.* *• Switch off compressors when production is down. If compressed air is needed for instrumentation, consider installing a separate compressor for this function; it will save wear on the main compressors as well.* *• When reciprocating compressors and screw compressors are used in parallel, always maintain screw compressors at full load. When partial loads are required, use the reciprocating compressor and shut down the screw compressor.* *• Minimize the air dryer regeneration cycle by installing a controller based on dew point measurement.* *• Enclose compressors (if applicable) to prevent heat infiltration into buildings, if not desired.*
Medium cost	• Replace older, high-maintenance air-engine driven equipment with new, high-efficiency type. • When many users demand relatively low-pressure air, consider the economics of installing a separate distribution network. • Install a pre-cooler to cool the inlet air and remove most of the moisture. • Consider installing electronic condensate drain traps (ECDTs) to get rid of the water in the receiver and piping. No air is wasted when the water is ejected; as opposed to the standard practice of cracking open a receiver drain valve for continuous bleed-off. ECDTs are extremely reliable. The payback period on the investment ranges from 8 to 24 months. • Install a large compressed air accumulator tank to reduce compressor cycling. • Review all operations where compressed air power is being used and develop a list of alternative ways to perform the same function. • If compressors are water cooled, look for ways to recover heat from the cooling water circuit. • In multiple-compressor installations, schedule the use of machines to suit the demand, and sequence the machines so that one or more compressors are shut off rather than have several operating at part-load when the demand is less than full capacity. • Make piping changes necessary to shut off production areas, e.g. packaging, when there is no demand (off shifts, weekends).

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

Case study: Is my compressor sized properly to meet demand? (brewer-contributed study)

Most of the literature available on compressed air focuses on reducing leaks and pressure in a system. Though these elements are important, one of the most basic aspects of a compressed air system is neglected. Has it been sized correctly to meet demand? Generally, an undersized system is identified quickly because it provides direct feedback to operations when it does not have enough air. However an oversized system is not as obvious and can be very costly to operate and maintain.

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

The end result was a system that was cycling excessively, resulting in increased maintenance and electricity costs. Since the system was oversized, saving leaks did nothing to actually help the bottom line. Reducing consumption would have only resulted in more air being blown off and wasted.

Results: As a result of the measurements and an understanding of their demand, the system was sized with one 75-HP fixed speed unit and one 75-HP variable speed unit with a large surge tank. With a good understanding of the load profile, they were able to size the system effectively and install a system that reduced the electricity used by the compressed air by 30 percent.

Additional information: Natural Resources Canada's Office of Energy Efficiency has supplementary and useful information on compressed air on their Web site under Industrial Energy Efficient Equipment at oee.nrcan.gc.ca/industrial/equipment/compressed-air/index.cfm

7.8 PROCESS GASES

Carbon dioxide (CO_2) and sometimes **nitrogen (N_2)** are process gases that have many product quality related uses in breweries. They are used to carbonate or nitrogenate the product. They prevent oxygen from coming in contact with beer when filling and emptying holding vessels, pipes and during transfers. They are used for dilution water conditioning, in bottling, canning and kegging, and lastly when dispensing 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 detergent on account of its neutralization. For beer conditioning, nitrogen is often used in a mixture (30 to 60 percent) with CO_2. Its use in beer produces a much denser and stable foam head with finer bubbles, as has been practiced by an Irish brewery for decades. However, the decision to use nitrogen is preceded by production and/or marketing considerations. Due to the lower density of nitrogen and the fact that the use of oxygen-free gas in the brewery is controlled by volume rather than by weight, the use of nitrogen can reduce the cost of gas by between 30 to 50 percent of the equivalent costs for CO_2.

CO_2 is a product of yeast metabolism during fermentation of wort. Theoretical calculations show that 52 percent of fermentable sugars in wort will be converted into CO_2. This translates to a theoretical yield of 0.43 kg per degree Plato (°P) 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 liquefiable, CO_2 must be at least 99.8 percent 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 percent 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 having a direct and significant influence on beer quality. That aspect must govern, first of all, its collection, handling and use in a brewery**, including checking for absence of flavour taints in it.

Even from CO_2 streams collected with gross air contamination (e.g. 20 percent), it is possible to recover pure CO_2 by means of low-temperature distillation. Collection may start as soon as the fermenter has been filled. The first gas, mostly air, will be diluted with streams from other

fermenters. Low-temperature distillation plants have a better collection efficiency of 0.28 to 0.33 kg per degree of attenuation. Moreover, the method allows for simplification of pipework, and valving that can influence the return on investment (ROI).

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

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

Process gases: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• Find out the CO_2 mass balance in the brewery. Purchase or rent gas flowmeters. For the gaseous flow, the thermal mass type with a high turn-down ratio of about 100:1 is suitable; for the liquid flow, a meter utilizing the Coriolis Effect is effective as it is independent of density, conductivity, viscosity and temperature. • *Detect and eliminate all leaks.* • *Shut off gas when not in use, e.g. on the bottle and can fillers.* • Consider blanketing fermenters with CO_2 prior to filling to reduce wastage through venting before collection and to increase yield. • Review the selection of bowl pressure in the filler. Any reduction of the bowl pressure and the reduction of the on/off control limit range (a modulating pressure control would help) will produce savings. • Review the use of gas on the canner (invariably a very large CO_2 user) and the position and state of the nozzles. • Limit the unnecessary use of CO_2 in storage tanks when the gas pressure is too high (0 to 1 bar(g) should be sufficient). A wasteful practice is to increase pressure while emptying 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 shown good results. That collection point was correlated to 99.5-percent CO_2 purity.* • *Review the contract with your CO_2 supplier; shop around for better prices and service.*

Medium cost	• Install flowmeters in a hierarchical fashion, e.g. a main meter supported by various levels of sub-metering to measure all gas usage. • Consider cross-connecting tanks to reduce CO_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	• Install a compressor and a storage balloon to capture flue gas for use in effluent pH adjustment/neutralization. • Eliminate wastage through the use of dead-weight valves when pressurizing tank before filling. They regulate pressure by venting excess rather than by stopping supply. Replace with appropriate control system. • Automate the collection of CO_2 gas from all fermenters through on-line gas purity measurement based on thermal conductivity (for CO_2) and/or 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.

7.9 UTILITY AND PROCESS WATER

Brewery operations are water-intensive. Specific water consumption (SWC) is a common measure, expressed as a ratio of hl of water to hl of beer.

Internationally, the Campden BRI together with the Dutch company KWA undertook in recent years a number of brewery water use surveys. The latest, in 2007, included 130 breweries, all bigger than 500 000 hl. The SWC range was 2.3 hl/hl (this was the best practice) to 8.8 hl/hl, with the top 10 percent (decile) having the SWC at ≤ 3.5. Table 7-6 shows the results a SWC survey done in the UK.

Table 7-6: A U.K specific water consumption survey

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

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

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

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

Water as raw material	1.3 hl/hl or 20 percent
Heat transfer	0.7 hl/hl or 10 percent
Cleaning duties	2.9 hl/hl or 45 percent
Other (including losses)	1.6 hl/hl or 25 percent

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

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

Annual water costs in a brewery are substantially lower than energy costs, but water conservation is a tangible, high-visibility action to which everybody can relate and which everybody would likely support. Undoubtedly, there are opportunities for conservation in any brewery. In the processes, water discharged from one operation could be piped in another, etc. The cost of water in a brewery has two components: the cost of water purchased and the cost of sewer charges. **The brewing industry was able to reduce the sewer charges by both the amount of water that went into the product as well as by the brewhouse evaporation loss.** (For excessive contamination of the drained out wastewater, extra effluent surcharges may be applied.)

Leaking valves and taps, loose joints and leaking pipes can cost the brewery a lot of money over time. Chances are that in a brewery, there may be several leaks at any given time; and the losses add up (Table 7-7). Associated costs of electricity to operate pumps, fans, water treatment costs, and maintenance increase the financial losses further.

Table 7-7: Water leakage and associated costs and losses

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

* Approximate cost at $2/$m^3$ purchased water and $2/$m^3$ drained-out water; the figures are rounded off. Use your actual costs to calculate the potential financial loss in your circumstances.

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

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

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

Cooling of air compressors requires close control of the cooling water temperature as well. However, both undercooling and overcooling can cause serious mechanical damage to an air compressor, and it is best to consult with the air-compressor manufacturer.

In all projects involving the heat content of water, proper insulation of tanks and pipes is necessary. Pipes carrying hot or chilled water (or wort or beer) should be well insulated to prevent heat loss or gain. Chilled-water piping should also have a vapour barrier to prevent condensation from saturating the open-fibre insulation. The hot water energy potential can provide useful service in

other than technological operations (mashing, sparging, washing, pasteurizing, etc.) such as in-space heating, steam generation, to temper make up air, as well as, through the use of heat pumps, for air conditioning. Benchmarking tools such as the brand WaterSaver®, are available at www.bri-advantage.com.

Case study: Minimize 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; 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.

New flow rate formula

The new flow rate is determined by the formula:

NF = {(29°–18°C) : (63°–18°C)} x OF; where
OF = old flow rate, L/h
NF = new flow rate, L/h

Savings are calculated using the formula:

CS = L x HR x CF; where
CS = cost savings, $/y
L = OF – NF, expressed in m^3
HR = yearly operating time of the compressor in hours, h/y
CF = cost of water consumption, $/$m^3$

Results: The simple payback period 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: Optimize the hot water system in the brewhouse

In a European brewery with an 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.

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

Case study: Install a 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.

Results: 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 one year.

Utility and process water: Other energy and water management practices and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	Note: Many of the items below should be part of the preventive maintenance (PM) or predictive maintenance schedules. • *Examine product scheduling, and vessel and equipment cleaning practices, where economies in water consumption (e.g. in water reuse or in CIP) can be obtained easily.* • *Examine water use patterns and reduce water consumption to the minimum necessary.* • *Maintain the system; stop leaks promptly.* • *Reduce pump-operating time where possible.* • *Do pump seals leak? Replace leaking seals ASAP.* • Are any pumps fitted with packing-gland seals? Consider replacing these pumps with new units with mechanical seals. • *To prevent water losses, inspects pipes frequently and repair leaks promptly.* • *Instil good housekeeping practices in all employees, e.g. do not run water hoses or taps uncontrolled (especially in the cooled areas, where the water adds to the refrigeration loads).* • *Do not let the eyewash fountains run as a drinking water source; provide drinking fountains instead.* • *Ensure that water supply for processes stops during idle periods (e.g. after-filler bottle crown flush, can rinser, last rinses in the bottle washer, etc.).* • *Remove stagnant, redundant branches of the water distribution network.* • *Monitor and control the cooling-water temperature so that the minimum quantity of water required to perform the cooling is used.* • *Water pumps should be shut off when the systems they are serving are not operating. This measure will reduce the electricity costs for pumping, and in case of cooling water, the cost of water treatment.* • Optimize pump impellers (change out) to ensure that duty point is within the optimum zone on the pump curve. • *Maintain pumps through regular inspection and maintenance to monitor for early indications of failure.* • *Strainers and filters should be checked regularly to ensure that they do not become clogged; clogged filters cause losses in pipeline pressure.* • *Reduce evaporation from tanks by installing (or closing) covers.* • *Check and adjust, as necessary, the appropriate water heating set points, aiming at the minimum required temperature levels. Consider switching off the heating regime for weekends and holidays.*

	• *Prevent or minimize water overflow occurrences (especially hot water).* • *Maintain proper control over water treatment to ensure that design flows are maintained.* • Maintain properly monitoring and controlling equipment. • Ensure calibration or verification of the temperature and pressure sensors. • *Identify all hoses and ensure that the smallest diameter necessary is used for the task.* • *Review the bottle washer operation.* • Ensure that tunnel pasteurizer operates in a thermally balanced mode. • *Ensure correct function of spray nozzles in the tunnel pasteurizer.*
Medium cost	• Reuse and/or recirculate cooling waters and process waters imaginatively, e.g. use pump seal water to serve as air-conditioning. • Use process or cooling water as a heat-exchange medium in your ventilation or heating system. • Consider placing a water/air heat exchanger system inside the brewery, to help with the heating load in the winter. • Collect uncontaminated "wasted" water if the rate of its generation exceeds the rate of the immediate reuse, rather than emptying it down the drain. Install an inexpensive FRP off-the-shelf tank or a second-hand vessel for the collection and use of the water later. Size these holding tanks properly. Use these collection vessels to even out the supply/demand ratio in your water multiple reuse projects. • Remove existing design flaws such as bottlenecks, sharp elbows, wrong-sized valves that restrict flow. • If pump flows vary consistently, consider using variable speed drives or two speed motors. • Collect uncontaminated cooling water for reuse. • Reuse all rinse water from cleaning operations (with due regard to product quality implications, wherever possible, for example the cleaning-in-place (CIP) last rinse. • Reduce water heat loss or gain by proper insulation of pipes and vessels. • Install water system expansion tanks on closed loop systems, to serve two purposes: When the water is hot, wastage through relief valves will be prevented. When the water is cold, the contracted volume would normally demand make-up water to keep the system filled. • Reduce friction losses and the associated pressure drops by streamlining and correct-sizing the water pipes. • Reduce water leakage/wastage by bringing the water pressure down in areas where high pressure is not needed. • Review correct size and choice of water pumps. • Install water flow regulators for sanitary uses; delayed closing or timed flow taps on wash hand basins and reduced-flow shower heads. • Install water meters in different process areas to monitor consumption on an ongoing basis. Use the data to identify zones, equipment and crews with either inconsistent or inefficient performance to correct deficiencies and to set progressively tighter consumption targets. • Install the European-type on-demand gas water heaters for sanitary use (as a brewery did).

	• Review the areas where high-volume, low-pressure rinsing or flushing makes sense (e.g. at the bottle filler), and where the use of low-volume, high-pressure (nozzles) water flow is called for. • Fit hoses with automatic cut-off valves where appropriate (guns). • Install delayed closing/timed flow taps on wash basins in the restrooms. • Consider replacing old hot water boilers with high-efficiency units (about 95 percent with condensing heat recovery).
Capital cost	• Implement a plant-wide water system with multiple reuses of process water, on a heat cascading principle. • Can a once-through system be converted to a circulating system? Revise the water distribution system to incorporate multiple reuse (recirculation) of process water wherever possible, employing suitable heat recovery regimes, and implement the measures. • Install closed-loop cooling water systems (cooling towers) to eliminate once-through cooling water (double costs on water and sewerage). • Review pump sizing, water pressure requirements and delivery distances versus the piping diameter. Often, smaller pumps but larger diameter piping – to reduce friction losses, provide better energy efficiency and make better economic sense when all costs are considered. • Upgrade pumps. • Streamline piping systems. Often, the brewery grew by adding new area or processes without much thought given to piping systems. Remove redundant, unused branches. • Make water management part of computer-monitored and controlled system of overall brewery utilities management (M&T technology, described elsewhere in this Guide). • Consider employing heat pumps for the combined application of heat extraction and provision of chilling to process water and other fluids. • Consider using waste heat to drive wastewater evaporator for sludge disposal (if you have an on-site wastewater treatment plant, WWTP).

7.10 SHRINKAGE AND PRODUCT WASTE

Have you dollar-quantified *all* components of poor quality in your brewery? *(Some examples follow.)*

Poor quality, which is also represented by reworked, rejected and scrapped product, represents 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 effort to improve things. A well-implemented management system such as using the ISO 9001:2008 international standard principles dealing with quality management systems, the HACCP norm, and the ISO 14001:2004 environmental management standard, will minimize occurrences of

product-in-process being reworked or rejected and finished product being scrapped. Omitting the serious negative product-quality implications, Table 7-8 shows some examples of energy waste and the common solutions.

Table 7-8: Energy waste – Process problems and solutions

Process problem	Commonly adopted 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. loss of profit
- decreased productivity
- increased direct labour expenses and indirect expenses; may include overtime
- wasted energy in pumping, heating and cooling of large volumes of water and beer (i.e. wasted fuel, steam and 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 cumulative losses over a period of time can be quite significant. Breweries should analyze and quantify some recent occurrences of losses listed above in order to assess the negative impact they have on the brewery on an annual basis.

Shrinkage and product waste: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Document process procedures and work instructions, with designations of responsibility and accountability.* • *Monitor routinely and quantify losses cumulatively over a period of time, to report them and to prevent or limit their occurrences.* • *Educate all employees about the cost and other negative implications of poor quality production. Solicit their input and ensure their participation in the remedial and preventive actions.*
Medium cost	• Implement management systems (along ISO 9001, HACCP and/or ISO 14001 standards), alone or in combination to ensure quality production and due care of environmental issues.

7.11 BREWERY BY-PRODUCTS

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

Brewery by-products: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Collect spent yeast and spent grains with minimum moisture content.* • *Review the existing contract with spent-yeast and spent-grains haulers.* • Investigate more profitable ways of by-product disposal. • Investigate composting or tillage, e.g. diatomaceous earth, wastewater treatment plant sludge, undistillable waste beer.
Medium cost	• *Collect and add trubs to the spent grains.* • Collect waste beer for off-site disposal or sale.
Capital cost	• Install/upgrade drying equipment to take advantage of modern, energy-saving technologies, of which many are suitable for spent-yeast processing and spent-grains drying (spray-drying and ring-drying for spent yeast, fluidized-bed and tube-shell steam drying for spent grains, etc.) • Distill alcohol from waste beer and sell it; evaporate the stillage in multiple effect vacuum evaporators and add to the spent grains.

7.12 WASTEWATER

Wastewater poses a problem for any brewery. Not only do breweries produce a lot of wastewater, it is also loaded with organic and inorganic matter making it expensive to treat on site or have it treated off site. The best performers have a ratio of wastewater discharged to beer produced of 1.5:3.5. The ratio reflects water contained in the product, evaporation losses in the kettle and evaporative condensers and water contained in spent grains, trubs and spent yeast.

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

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

Municipal treatment plants and municipal treasurers welcome brewery wastewater because it often offers a chance to collect significant effluent surcharges due to the high biochemical oxygen demand (BOD_5) loading for the treatment plant. The typical range is 1000 to 2500 mg/L BOD_5. In any municipality, the maximum permissible contaminants of wastewater are set by relevant by-laws.

Depending on the location, wastewater may include the following charges:

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

Often, the two pollution indicators, BOD_5 and SS, are combined in an effluent surcharge formula, and others are combined or hidden in areas such as water supply costs. Municipalities, faced with rising costs for sewer system upkeep are showing little tolerance for pH transgressions that exhibit wear and tear on the sewer pipes, and are forcing industries to comply with their bylaws. Therefore, one often finds Canadian breweries installing pH-adjustment systems on their brewery processes effluent.

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

Due to tighter pollution criteria, storm sewers can be contaminated by spilled oil or fuel from parked cars, spilled spent yeast or spent grains from loading, and spilled beer from road tankers. Contaminated storm sewer water can pose serious, costly difficulties with a number of authorities. Hence, procedures must be implemented to prevent storm sewer water contamination.

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

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

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

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

A brewery can save significant sums of money and improve the quality of the effluent it produces 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 brewery, savings can range from small amounts of money to million-dollar sums. It is worthwhile to examine each brewery separately.

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

Minimize in-brewery beer losses by typically 2 to 5 percent of total beer production by making improvements in product-in-process management.

Wastewater: Other energy and water management opportunities and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Remove hot wort trubs with the minimum amount of high-pressure water.*
	• *Dispose of hot wort trubs by mixing them with spent grains.*
	• *Prevent leakage of spent-grains liquor from the spent-grains holding tanks.*
	• *Investigate opportunities for profitable or less expensive disposal of spent yeast and waste beer.*
	• If operating a WWTP:
	  • Review the efficiency of oxygen transfer to the mixed liquor;
	  • Upgrade the equipment, adjust the aeration rate to suit the load and the ambient temperature;
	  • Consider the power demand implications;
	  • Avoid using high-pressure compressed air for aeration;
	  • If using sub-surface air dispersion, review the state of membranes (discs, nozzles);
	  • Review the efficiency of electric motors and drives as appropriate.
	• Investigate off-site disposal of waste beer (e.g. to a distillery, feed-lot operations, etc.).

Medium cost	• Modify process equipment and/or process procedures to prevent effluent contamination, e.g.
	  • Collect all waste beer for off-site disposal;
	  • Reuse 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 drain it out).
	• Use biogas from an anaerobic plant (if installed at a brewery) to augment the brewery's energy needs. Negotiate with appropriate authorities the ability to discharge some non-contaminated effluent streams such as pasteurizer and compressor cooling waters into storm water sewers (assuming that no further recycling opportunities exist for these streams).

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

7.13 BUILDING ENVELOPE

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

It is often nearly impossible to upgrade wall insulation inside buildings, for many reasons. In such cases, it may be possible to add insulation to the external side of the buildings and cover it with new weatherproof cladding. See Table 7-9 for the thermal resistance of insulation based on degree-day zones.

Table 7-9: Minimum thermal resistance of insulation
(Based on degree-day zones. Consult your local building permit office for guidance.)

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

Reference: Ontario Building Code 1997. For illustration only.

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

Windows can present both a challenge and an opportunity for energy conservation. Many older brewery buildings have single-glazed, inadequately sealed windows. They are often dirty, not cleaned, forgotten by maintenance or cleaning crews (see the influence on lighting). Replacing them with double or triple-gazed units is expensive. Instead, fitting them with panels of plastic or glass-fibre may be used to advantage. Also, the glass, exposed to the sun, may be fitted with a sun-deflecting film, to reduce heat gain (in the summer). Table 7-10 shows the RSI value for various types of windows.

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

Table 7-10: RSI / R insulation values for windows

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

Some facts about glazing:

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

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

Building envelope: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Repair broken windows, skylights and doors.* • Check the thickness of insulation in walls and roofs. • *Examine all openings for cracks allowing air to leak in and out the building.* • *Caulk or weather-strip the cracks.* • *Inspect the loading dock seals for proper fit and damage.*
Medium cost	• Seal the building first, to reduce air leaks – both infiltration and exfiltration – through openings such as doors and windows. • Consider shading or curtaining windows on the inside, or shuttering them on the outside, to keep the summer heat and winter chill out (watch for building codes and ASHRAE regulations). • Plant shrubs and trees around the buildings. • Install sun shades (sun trellis) over the windows to reduce summer heat gain. • Review the possibility of installing automatic door closers, vestibules, or revolving doors. • Locate the heat exchanger for the flue gases cooling inside the brewery building; it will help heat it in the winter. An additional benefit: worries about freeze-up or charging the system with antifreeze are minimized. • Install an automated damper system on the air compressors to keep the heat in the building during the winter. • Install air curtains at loading bays. • Consider linking exhaust fans in washrooms, kitchen, etc., to the light or equipment switch. • Consider reversing the roof exhaust fans in areas where it is possible (e.g. relative absence of dust), in the wintertime, to mix with and temper the outside air to provide heat to areas below. • Consider installing double-door vestibules or wind breaks in north-west locations of the openings.
Capital cost	• Add measuring and monitoring, and control devices. • Incorporate the building features into the total plant energy management system. • Evaluate the economics of replacing present insulation type with another type. Consult with unbiased professionals. • Consider innovative use of passive or active solar heating technology for space and/or water heating, especially when combined with improved insulation, window design and heat recovery from vented air. • Consider installing a solar wall (e.g. SolarWall™, Trombe) on the building's south or south-west sides to provide effective heating. • Consider using evaporative cooling of flat roofs to reduce air-conditioning loads in summer. • Review the adequacy of the building envelope's thermal insulation, particularly roofs, and correct if required. • Consider installing a new insulated roof membrane with covering of heat-reflecting silver-coloured polymeric paint to lower the heat transmission. • Consider using heat generated by equipment (e.g. compressors, pasteurizers, wort coolers, economizers, etc.) for building heating in the cold weather. • Consider upgrading windows. • Consider upgrading doors and bay doors.

Take advantage of your climate – cellars (brewer-contributed study)

Historically this brewer's cellar exhaust fans turned on based on CO_2 levels in the cellars and turned off when levels dropped down to acceptable levels. The fresh air make-up came from outside in the summer and with a damper closed, from inside in the winter so that -20°C air was not freezing lines.

Recommendation: They installed an extra damper with minimal automation and were able to temper make-up air and use outside air all winter long. Supply air to the cellars is consistently delivered at 1 to 2°C with the bulk of the air coming from outside. This is expected to have a fairly large impact on refrigeration loads in these areas. The plan is to apply this to other areas. Although the first approach should be to minimize CO_2 leaks in the cellars, processes are difficult to change with existing infrastructure and delays ensue.

7.14 HEATING, VENTILATING AND AIR CONDITIONING (HVAC)

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

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

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

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

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

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

Unnecessary exhaust of 10 000 cfm translates to about $3,000/y in heating costs.

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

Do not undermine the functioning of a well-designed ventilation system by leaving doors and windows open unnecessarily. Otherwise, it will never work.

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

HVAC: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Conduct a survey of HVAC in the brewery. Check the temperature of the workplace for adequacy and adjust as necessary.* • *Review the condition of HVAC equipment (function of louvers, control valves, temperature controller) and correct as necessary.* • *Ensure the HVAC equipment is serviced regularly either by outside contractors or by the brewery maintenance staff.* *Patiently, consistently and persistently try to implement a culture change, i.e. changes to employee behaviour towards energy management can lead to a virtually cost-less achievement of substantial savings. Some of the items are listed below:* • Close windows, doors and receiving/shipping bay doors in cold weather. • Report high ambient temperatures rather than opening windows (so qualified adjustments can be made). • Assign someone (e.g. maintenance) to switch-off machinery at the end of the work week. • Remove superfluous lights. • Prevent blockage of radiator and ventilation grids. • Ensure correct setting of controls on make-up air units. Lower the temperature setting, if possible. • Do not leave doors open, e.g. from the corridor into the cellars, external doors, etc. Doing so negates the HVAC settings in the brewery and the correct function of the HVAC equipment.

- *Install locks to thermostats and HVAC controls to prevent tampering and misuse by unauthorized employees.*
- *Eliminate heating or cooling of all unused rooms.*
- *Lower the thermostats for the weekends (say, to 15°C).*
- *Raise the thermostats a bit in summer and lower them a step in the winter, when possible (18°C should be a comfortable brewery building temperature).*
- *Lower the heating temperature in storage areas to as low as possible.*
- *Use "free cooling" with low-temperature winter air.*
- Install setback timers on thermostats controlling space heating during non-working hours.
- Use destratification ceiling fans in areas with high ceilings such as bottling halls. (Note: The usual 5' or 6' diameter Casablanca-make fans have lower energy requirements than central ceiling-level heating/ventilation air handling units. Also, in a pharmaceutical plant in Alliston, Ontario, very large diameter ceiling fans (12' to 16') were employed for gentler air circulation, with further energy savings.)
- *Check the adequacy of ventilation. Use the minimum acceptable ventilation. Find out whether the plant is under negative pressure due to too much air being drawn out or positive pressure from too much supply air being blown in.*
- Minimize building exhausts. Close off roof vent stacks in cooler weather/seasons to minimize heat loss. Make sure the dampers work.
- *Shut down exhaust or supply fans during non-working hours.*
- *Clean/exchange intake air filters regularly.*
- *Ensure that heating and air-conditioning systems operate only when required.*
- *When no production is going on, and on weekends, and especially during colder weather and in winter, reduce the amount of fresh air brought into the plant as much as possible.*
- *Turn-off air-conditioning units in the cafeteria and in the offices on weekends.*
- *After the hot air from compressors has been generated, re-circulate it back into the building for heating purposes (in winter).*
- *Keep the doors / loading bays closed to allow the ventilation system to work properly.*
- *Switch off ventilation and/or heating when not required.*
- *Shut down dust collection, ventilation and makeup air when not required.*
- *Assign someone to turn-off the fans, close the vents, etc. at the end of the week. Prepare a checklist so nothing is overlooked.*
- *Conversely, put someone in charge to switch it on at the beginning of the workweek.*
- Incapacitate some non-essential exhaust fans during the winter months (take the fuses out).
- Eliminate leaks and pressure loss points in supply and return air systems.
- Examine your current system. It might be that the original dust collection/exhaust system was designed to handle larger volumes of air than necessary for ordinary plant operations. Perhaps some of the fans could be taken off line, at zero cost, for the immediate benefits of
  - reduced maintenance
  - lower energy costs
  - reduced emissions
  - reduced noise

	You can simply verify this by turning the selected fans off and observing the result. • Pay attention to the upkeep of your baghouse/dust-collection system. Monitor both its integrity and resistance (i.e. proper functioning) by a differential pressure gauge (e.g. water column gauge). • Monitor CO (carbon monoxide) levels regularly, either by manual checking at head level or by installing an automatic sensor-driven alarm in cellar areas. It will give an additional indication of the ventilation effectiveness. • *Keep the motors on forklift trucks and other brewery vehicles well tuned to reduce the excessive release of CO into the brewery atmosphere. Such excessive release of CO would, in turn, increase ventilation demand.* • *Do not let the motors on forklift trucks idle; switch them off when not in motion.* • *Watch for "short-cutting" of heated make-up air directly to a nearby exhaust fan.* • *Delay the start of brewery ventilation at the start of operation until the heat of bottle-washing, pasteurizing, etc. has warmed up the air inside.* • Where required, cut small openings into large doors to allow the passage of forklift trucks; use transparent curtains to prevent continuous blasts of cold air from the outside.
Medium cost	• Install infrared heating for large open areas (replace steam or hot water heating radiators) to heat people rather than space; in addition, radiant heaters do not require air-handling mechanisms, saving further energy. • Minimize unwanted infiltration of outside air into the brewery also by other means (reseal cracks, repair or replace doors, link loading bay doors opening to the activity, etc.) • Use economical radiant heating directed at workstations rather than general space heating. • Install strategically located exhaust hoods over dusty/hot areas. Make sure that they are amply dimensioned, so the heat or dust does not escape into the general space. • Recapture the heat that accumulates high up in the brewery spaces; push it down in the wintertime (filter it, if required) and control it thermostatically should the outside temperatures be extremely low. • Fit the exhaust fans with variable speed drives to match the ventilation rate to the need. • Investigate whether you can supply outside air directly to a particular operation to conserve the heated plant make-up air. • Install high-velocity air curtains at loading bays and other large openings.
Capital cost	• Use reflective insulation, or paint flat roofs white over refrigerated areas. • Install thermostatic air vents. • Evaluate the application of recently developed regenerative rooftop heat recovery ventilation systems. • Replace the general ventilation of the entire area with locally situated, hooded exhausts from areas that need to be ventilated. • Consider the provision of fresh air and constant temperature in the brewery by installing a new ventilation system using a rotary heat exchanger. The warm exhaust air heats the incoming air in the exchanger. The temperature is controlled by the number of revolutions of the exchanger. • Consider using heat pumps (or ground heat pumps) for combined heating and cooling of the brewery facilities.

7.15 LIGHTING

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

Bulb efficiency:

Incandescent = 100 percent
Fluorescent = 300 percent
Metal halides = 400 to 600 percent
HP sodium = 450 to 700 percent
LED = higher by several orders of magnitude

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

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

It is worthwhile to consider this fact for several reasons. Adequate lighting levels that correspond to the age of the workers have many tangible and intangible benefits that are often overlooked:

- improves morale and reduce absenteeism
- positively influences quality (i.e. resulting in improved customer satisfaction)
- allows for better control of costs by reducing defects and rejects (particularly in packaging, at pasteurizer bottle inspections, packaging, labeling, etc.)
- provides inducement to experienced older workers to stay on rather than retire early
- improves housekeeping and safety records (i.e. cleaner, more orderly workplace and lower accident and insurance costs)
- positively influences the company's image and the personnel's self-image

Where applicable, try to take advantage of natural daylight (skylights, windows). Think about ways to facilitate the window/skylight cleaning.

Focus on improvements to energy-efficient lighting fixtures, rather than on reducing the lighting intensity in workplaces to reduce lighting costs.

The first step to reduce energy consumption associated with lighting is to survey the lighting in all locations of the brewery to assess the equipment, use patterns, and adequacy throughout the brewery. An investment in a lux meter (measuring lighting levels in lumens per m^2) will quickly pay off.

It needs to be mentioned again that measures taken to reduce electricity consumption by lighting systems helps reduce emissions from thermal electricity-generating stations. Refer to Section 8 dealing with emissions.

Case study: Replace standard fluorescent lighting with energy-efficient tubes

A brewery had 956 standard lamps (75-W, 8 feet), using them, on average, 8 hours a day, 5 days every week. They had a ballast factor of 1.1, electricity cost of $0.09/kWh and a demand charge of $13.60/kW per month. The use of high-efficiency lamps, saving 15 W per tube, generated annual savings of $5,140.

Results: 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 17 percent 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 period of 3 months, second year of 1.6 months, etc., until all savings were completed in the sixth year.

Lighting: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• Also look up items under Section 7.15. • *Educate employees about good housekeeping practices, encourage change of wasteful habits and encourage employees to shut off lights when not required.* • *Assign responsibility for turning lights off at the end of the production day, and turning them on prior to the start of shift in each department and in general areas.* • *Ask Security or cleaning staff to ensure that lights are turned off.* • *Turn off fluorescent lights when they will remain off for at least 15 minutes.* • *Turn off high-intensity discharge lights when they will remain off for at least an hour.* • *Establish a regular cleaning schedule for lamps and of light fixtures shields, particularly in dusty environments (carton cutters, malt grist mill room, etc.).* • *Institute a regular lamp-cleaning program that will maintain lumen output and reduce total lighting requirements.* • *Implement a regular re-lamping program.* • *When re-lamping, it is most economical to change all the lamps at the same time.* • *Reduce or switch off unnecessary outside floodlights and signs.* • *Reduce parking lot lighting when not in use.*

Lamps get dimmer with age yet continue to use the same power: re-lamp.	• Verify the light level in all brewery areas to ensure adequacy, and eliminate excessive lighting levels (e.g. corridors, storage areas). • Invest in a light meter (lux meter); it will quickly pay for itself • Examine opportunities for de-lamping of excessively lit areas. When doing so, remove the ballasts for fluorescent and high-pressure sodium lighting as the ballast consumes electricity even when the bulb is removed. • *Examine opportunities for reducing lighting hours.* • *Check the condition of the fluorescent tube protector tubing for yellowing and dirt.* • *Clean skylights, if applicable.* • When installing new lighting, opt for a low-energy, high-efficiency types. • Use motion detector switches where an operator's presence is intermittent and/or where feasible (storerooms, cellars, offices, etc.) to reduce power consumption. • *Minimize lighting use in cooled areas as it adds to the heat load.* • Reduce lighting to the minimum safe level. Install motion detector switches on exterior security lighting.
Medium cost	• Use motion-detector light switches where feasible, e.g. offices, storerooms, etc. • Use a programmable or photocell-governed system or motion-detector light switches for general exterior lighting. • Reposition the lamps placement where it is not effective, e.g. when shining on top of stacked pallets, bales of hops, on top of tanks, to the pasteurizer or the soaker, etc. • Install automatic lighting control by time clock that will switch off lights at predetermined times (with overriding provision for local areas). • Provide adequate task-focused rather than general space lighting, i.e. reduce the level of general lighting to a minimum and provide task lighting at workstations, as required. • Where the environment permits it, paint the walls and ceilings with white or lighter colours and use the light reflectance to improve the brightness of the workplace. • Replace old ballasts with an energy-efficient type (especially important if power factor is low and the brewery pays penalties as a consequence).
Capital cost	• Replace lower-efficiency lighting with more efficient types (e.g. mercury lamps with HP sodium lamps). • Replace all standard fluorescent tubes with high-efficiency tubes (T series). • Replace existing lighting with discharge and low-energy lamps whenever possible. In high-ceilinged areas, substitute fluorescent or mercury vapour lights for metal halide or sodium lamps. • Where conditions permit it, lower the ceiling lamps to increase light intensity on the floor; it may even lead to a reduction in the number of existing lamps.

7.16 ELECTRIC MOTORS AND PUMPS

Electric motors

The efficiency of older electric motors is generally much lower (as is the power factor) than that of the new generation of high-efficiency (HE) motors. HE motors have efficiencies above 93 percent (a function of motor horsepower: the higher the horsepower, the better the efficiency). The summary replacement of running old motors with HE models is often difficult to justify, unless they run close to 24 hours a day and the power cost savings provide a good return on the investment. When the motors need to be replaced or sent for rewinding, HE motors should be purchased instead. Provide cost-justification based on marginal motor cost difference, when the time comes for rewinding or replacement of the old motor. This should be encoded in a purchasing policy.

Oversized motors or idling motors waste electricity and cause poor power factors. That is frequently the case in motors operating baghouses and air compressors, usually among the biggest in the brewery. These motors, among the hardest working, are especially susceptible to burnouts by electric induction or equipment harmonics.

Pumps

In breweries, most pumps have electric motors. There are two types of pumps based on operating principles:

- centrifugal pumps (dynamic pumps) – add kinetic energy to the liquid to move it along (e.g. for water, wort, beer, wastewater)
- positive displacement pumps – provide for a constant volumetric flow for a given pump speed, given by the volume of the pump cavities (e.g. for yeast slurry, diatomaceous earth slurry, wastewater sludge)

The design of a proper pump and its application is a complicated matter. Both pumps and their drives must be large enough to overcome the resistance of: the pump drive, the conveying pipe network, the pump seals and the elevation difference between the pump and the end user. All these factors influence the power requirement of the pump in a significant way. Energy requirements, and hence operating costs, can be reduced by selecting high-efficiency motors, pumps and drives, tailored to operating conditions.

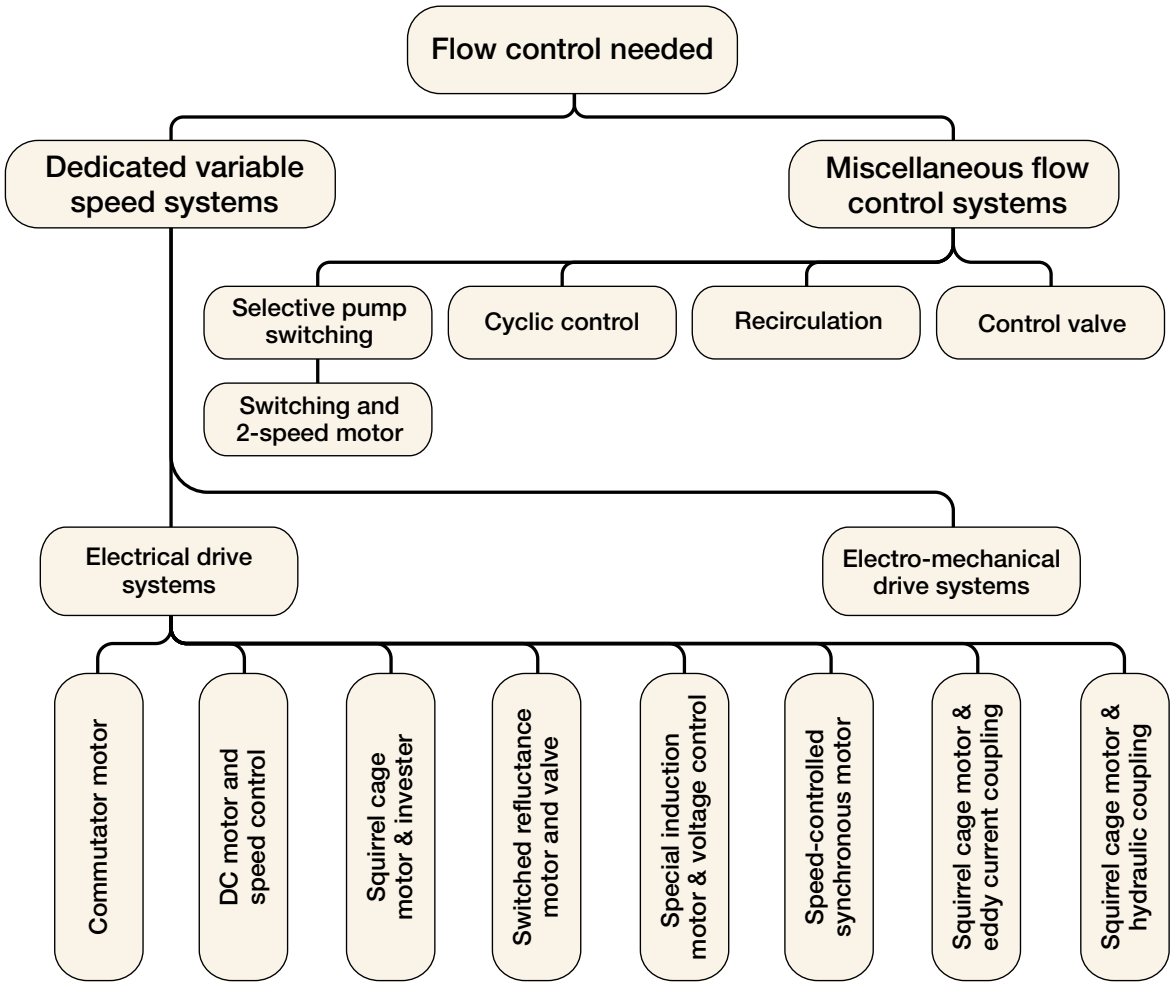
Pump seals also add to the frictional resistance of the shaft. The most common are the mechanical and packing-gland seals. The latter requires up to six times the power requirement increase that the mechanical seals need. Pump seals not only contribute to losses when they leak but compromise the integrity of the system and may contribute to oxygen pick-up and/or microbial contamination.

Review the deployment of your pumps. They should be properly sized so as to fit the flow requirements. See Figure 7-4 for efficient pump operation options. If the review shows that the pump is capable of producing more flow or head than the process requires, the following measures can be taken:

- When the flow load fluctuates, install a variable speed drive.
- When the flow load is constant, reduce the size of the impeller on a centrifugal pump.

- Optimize pump impellers (or change out) to ensure that the duty point is within the optimum zone on the pump curve.
- Maintain pumps through regular inspection and maintenance to monitor performance for an early indication of failure.

Figure 7-4: Options for energy-efficient pump operation



As per CADDET Energy Efficiency Newsletter #2, 1995

Case study: Replace standard drive belts on large motors with high-torque drive belts or energy-efficient cog belts

Every electric motor has some inherent inefficiency. Losses incurred by torque power transmission on machinery by the use of a standard V-belt, come from slippage, bending, stretching and compression of the V-belt. Although the V-belt has a maximum efficiency of 94 percent, under well-maintained conditions it only has about 92-percent efficiency. Replacing V-belts with cog belts, which slip less and bend more easily, 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, by about 2 percent and high-torque drive belts (HTD) by at least 6 percent. Moreover, cog belts last about 50 percent longer than standard V-belts.

The following formulae are used in the calculations:

PS = anticipated reduction in electricity, 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 percent for cog belts, 6 percent for HTDs)

Results: Using the electricity cost of $0.09/kWh and a demand charge of $13.60/kW per month, 16 motors totalling 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 period is immediate for cog belts at replacement time.

Assuming an installation cost of $300 per set of pulleys, the simple payback period for HTD in the above example is 1.5 years.

Case study: Use synthetic lubricants on large motors

A brewery with several large electric motors totalling 347.5 HP, with an average efficiency of 85 percent and an average load factor of 75 percent, with one shift operating using synthetic lubricants, would see a 10 percent reduction in energy losses. Using the consumption and demand rates from the previous case study, it is possible to calculate electricity savings of $1,050 per year.

The potential savings in energy consumption involved in switching to synthetic lubricants can be calculated using the following formulae:

$PS = HP \times (1 - \eta) \times LF \times S$
$ES = PS \times H$; where
PS = anticipated reduction in electricity, kW
ES = anticipated energy savings, kWh/y
HP = total horsepower for the compressors and other large motors, kW
η = average efficiency of the motors (e.g. 0.85)
LF = average load factor, %
H = annual operating, h
S = estimated reduction of energy losses through lubrication, %

Synthetic lubricants carry a price premium. However, they last much longer than petroleum-based lubricants, which offset the increased costs. The only implementation cost is that of a lubrication specialist.

Results: Assuming a cost of $800, the simple payback period is 9 months.

Case study: Variable voltage, variable frequency inverters

Variable voltage, variable frequency (VVVF) inverters are well established in induction motor control. A Japanese 2.2 million hl/y brewery investigated the use of VVVF inverters for its 3300 induction motors, used for pumping and other applications. The VVVF inverters allow the pump-motor speed to be continuously varied to meet load demand. Development of a standardized motor assessment procedure and detailed evaluation of 450 motors preceded the pilot installation.

Five pumps with an annual electricity consumption of 1501 MWh were selected. After the VVVF inverters were installed, the annual electricity consumption dropped to 792 MWh.

Results: This resulted in a savings of 709 MWh. The corresponding payback period was 1.9 years on average (at the time). The project also investigated the effects of noise interference on surrounding equipment and carried out measures to alleviate any problems that occurred.

Case study: Turn off equipment (motors) when not in use

An audit of a brewery 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 motors when not in use can be calculated using the following formulae:

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

$$CS = ES \times EC; \text{ where}$$

ES = realized energy savings, kWh/y
HP = horsepower of motors left on during the day, HP
CV = conversion factor (0.7459 kW/HP)
η = average efficiency of the motors, %
HR = annual hours of unnecessary idling time, h
IL = idle load horsepower consumption of the motors (e.g. 10 percent)
EC = consumption cost of electricity, $/kWh
CS = cost savings

Electric motors and pumps: Other EMOs and tips

Note: Points of interest particularly (but not exclusively) for small breweries are shown in colour italics.

Housekeeping, no or low cost	• *Verify that motors are correctly sized for the job.* • *Switch off motors and equipment when not needed.* • Install automatic controls for shutting down equipment when not needed. • Review motor burnout history and whether circuitries in the brewery need to be upgraded. • *Use the public utility as a resource: they can make suggestions as to demand reduction alternatives, points for metering, the way to measure consumption, and possibly to loan a load analyzer.* • Maintain and calibrate automatic controls on all equipment. • Control harmonic distortion passively and upstream: specify it in new equipment buying standards. • *Check connections in the motor box for signs of overheating.* • Perform regular vibration analysis of motors and drives. • *Shut down pumps when there is no pumping requirement.* • Ensure that packing glands on pumps are correctly adjusted. • Maintain clearance tolerances at pump impellers and seals. • *Check and adjust the motor driver regularly for belt tension and coupling alignment.* • Clean pump impellers and repair or replace, if eroded or pitied. • Implement a program of regular inspection and preventive maintenance for motors, and all pump components to minimize failures.
Medium cost	• Replace, as a matter of purchasing policy, old worn-out electric motors with new high-efficiency motors. • Install variable speed drives and soft-start options on electric motors. • Consider installing power load-shedding software in the electric motor control centres. The software serves as an electricity and process management tool. It monitors power usage instantaneously and adjusts to a set target for the maximum level of power it can use. It governs the consumption through a PLC. It can express real and predicted usage of power in kWh per unit of product and also in terms of costs, e.g. PowerPlusReporter® software, environmental and energy management programs from E2MS company. • Consider conducting thermography inspections for electrical hot spots detection, e.g. in couplings and contacts, which indicate mechanical sources of losses. For example, Fluke Co.'s heat detection gun can be used. • Replace packing gland seals with mechanical seals. • Trim pump impeller to match system flow rate and head requirements.

Capital cost	• Control harmonics that can interfere with and cause burnouts of motors. The harmonics may cause damage to capacitors installed to control the power factor, trip fuses, burn motors and overheat equipment. It is essential to control harmonics. Examine your local conditions. • Consider replacing power capacitors with microprocessor-based LRC tuning circuits, sized for each specific equipment and power load, to control the power factor for improved savings. In some establishments power factors close to unity, of 0.98 to 0.99, are routine. • When installing an energy management system, choose one with both analytical and reporting capability. • Consider installing a power monitoring system, with monitoring and targeting methodology, to manage electricity consumption in the entire brewery. • Replace outdated/unsuitable equipment with correctly sized new units.

7.17 MAINTENANCE

The topic has already been mentioned previously. However, it is important not to overlook the energy benefits of preventive maintenance.

The costs of having to shut down production, because of equipment breakdown, can quickly add up:

- loss of sales; loss of customer's confidence
- higher labour costs that may include overtime to make up for lost time
- higher overhead costs
- extra energy cost to keep the line on stand-by, etc.

If you have not done it already, try to figure out the cost of various components of one hour of downtime. It is likely that its energy component will be substantial. Planned preventive maintenance can help reduce the unplanned downtime, and should be a routine part of overall operations. Preventive maintenance is a very important part of an energy conservation program and energy efficiency improvements in any brewery. The chances are that the investment in preventive maintenance will pay off very quickly in both operational and energy savings.

When preparing a preventive maintenance schedule, do not forget to also include hand tools (particularly compressed-air-driven ones). Apart from extending the useful life of the tools, it will result in a reduction of compressed air usage (energy).

Predictive maintenance is one directed at avoiding failure within a time specified by an analysis of historical data. For example, because the bearings on an electric motor fail typically every 15 months, on an average, the predictive maintenance will call for scheduled bearing replacement every 12 months.

Books have been written on setting up a preventive and predictive maintenance, and professional software programs for it, with various degrees of sophistication and tie-ins into other general management modules (such as accounting, purchasing, parts inventory and payroll areas) are commercially available. While these may be affordable for the bigger breweries, even the small ones may set up a simple preventive maintenance schedule and program using spreadsheet (Excel) or even word (Word) processing software.

Case study: The importance of maintenance

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 (kg/h). On an annual basis, this corresponds to the 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 2100 kg to 3500 kg oil per year, which is enough energy to produce 580 to 1000 hl of beer at low consumption.

Results: The insulation of just 1 m of 89-mm steam pipe used 6000 hours per year will provide savings of about 450 kg of oil per year, or enough energy to produce about 120 hl of beer.

7.18 BREWERY PROCESS-SPECIFIC ENERGY EFFICIENCY OPPORTUNITIES

Many examples of energy efficiency opportunities in Canadian breweries have been mentioned in the preceding text. Technological advances, albeit of no "radical breakthrough" nature, have been made by many brewery equipment manufacturers in the 12 years since this Guide was first published. Beer technology is mature and well established all over the world. Radical concepts of the 1960's and later years such as continual brewing, continual fermentation and continual maturation of beer, have largely fallen short of expectations.

It is perhaps worthwhile to reflect on not-so-novel but proven technologies. The following is a brief list of the topics mentioned in the First Edition of the Brewery Guide which may stimulate thinking about actions that can help a brewery reduce its operating and energy costs and improve the profitability of its operations.

Combined heat and electrical power generation

In the deregulated Canadian electrical energy market, the combined heat and power generation (CHP) may be interesting for some breweries. One Canadian brewing company, Labatt Brewery in London, Ontario, adopted cogeneration, to take advantage of favourable Hydro policies at the time (1994). The technology is well-established and proven for application in many industries. Different types of turbines, running on various energy sources (natural gas, oil, but also waste, biomass, diesel and gasoline) are manufactured by many manufacturers. The power-to heat ratio of generation has been improving, nearing equity, and the total efficiency in the 80-percent range.

Other breweries may consider making the required large investment and ROI potential of this attractive technology.

Wort boiling advances

Attempts to optimize energy use and increase production efficiency led to various brewhouse technology modifications. For example, vessels were stacked up to reduce heat losses and pumping requirements; continuous mashing, separation and boiling processes were attempted; low pressure boiling was adopted by some; brew kettles were fitted with steam-heated coils and percolators to speed up and intensify wort boiling; external wort boilers were employed instead; etc.

Mechanical vapour recompression (MVR) and thermal vapor recompression (TVR) are proven, energy-efficient methods of brewing that have been employed worldwide. The methods regain a larger part of the latent vapours heat from the kettle, generated by boiling wort with exclusion of air. The heat obtained from the recompression of the vapours is reused 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 percent and requires only a relatively small investment.

Other systems have been invented, e.g. microwave wort boiling (by Huppmann of Germany).

Nine years ago installation of a Merlin™ thin-layer wort boiling technology, by the Steinecker Group, was planned by a brewery in Quebec. It claims many technological as well energy consumption advantages, compared to conventional kettle boiling or low-pressure wort boiling. It appears that the Merlin™ wort boiling is a promising, state-of-the-art innovation that offers technological and product quality advantages, energy savings and environmental benefits in reducing the generation of greenhouse gases, consumption of water and generation of effluent.

Beer flash pasteurization

Flash pasteurization is a not-so-new but seldom-employed method of beer pasteurization in North America. It can be used both for bottle packaging (often in combination with hot filling) and keg packaging. For breweries with well-controlled production and operating conditions, it may offer several major advantages, among them space and capital savings and savings of two-thirds on energy spent on pasteurization compared to the tunnel pasteurization process.

Tunnel pasteurization

New developments have led to the application of automatic pasteurization unit control systems by several manufacturers (e.g. KHS, Sander Hansen, Gangloff-Scoma). New types of tunnel pasteurizers incorporate features designed to reduce water and energy consumption (e.g. “Channel Pasteurizer” developed by Sander Hansen).

Microfiltration and ultrafiltration

With recent advances in the development of regenerable filtering media (cartridges and membranes) and separation technologies, microfiltration and ultrafiltration methods can be used. Their possible applications can include sterile filtration of beer (which obviates the need for energy- and water-intensive pasteurization), beer recovery, cleaning of spent caustic solutions from bottle washers and CIP systems, beer recovery, water conditioning, etc.

Spent-yeast and spent-grains drying

Several new, tested and proven modern energy-efficient technologies for drying brewery by-products use different media such as saturated steam, superheated steam or direct gas combustion. These systems are available to supplant traditional inefficient drum-drying (spent yeast) or direct-fire drying (spent grains) generally employed by some large North American breweries.

Vacuum distillation

A low-temperature distillation of CO_2 allows recovery of pure CO_2 from collection streams heavily contaminated with air. With this method, collection efficiencies can almost double in comparison with well-managed conventional collection methods and plants. Substantial energy and auxiliary raw material savings result.

Expert computer control systems

An expert computer system uses specialist knowledge, obtained from a human expert (including well-experienced employees about to retire), to perform trouble-shooting, problem-solving tasks such as diagnosis, advice giving, analysis and interpretation. By capturing and formalizing human expertise, such systems can improve the performance of businesses by

- cutting the time taken to perform complex tasks, thereby improving productivity
- reducing operation times
- improving the quality of advice and analyses to enhance both operating efficiency and product quality
- making rare expertise readily available, thereby alleviating skill shortages

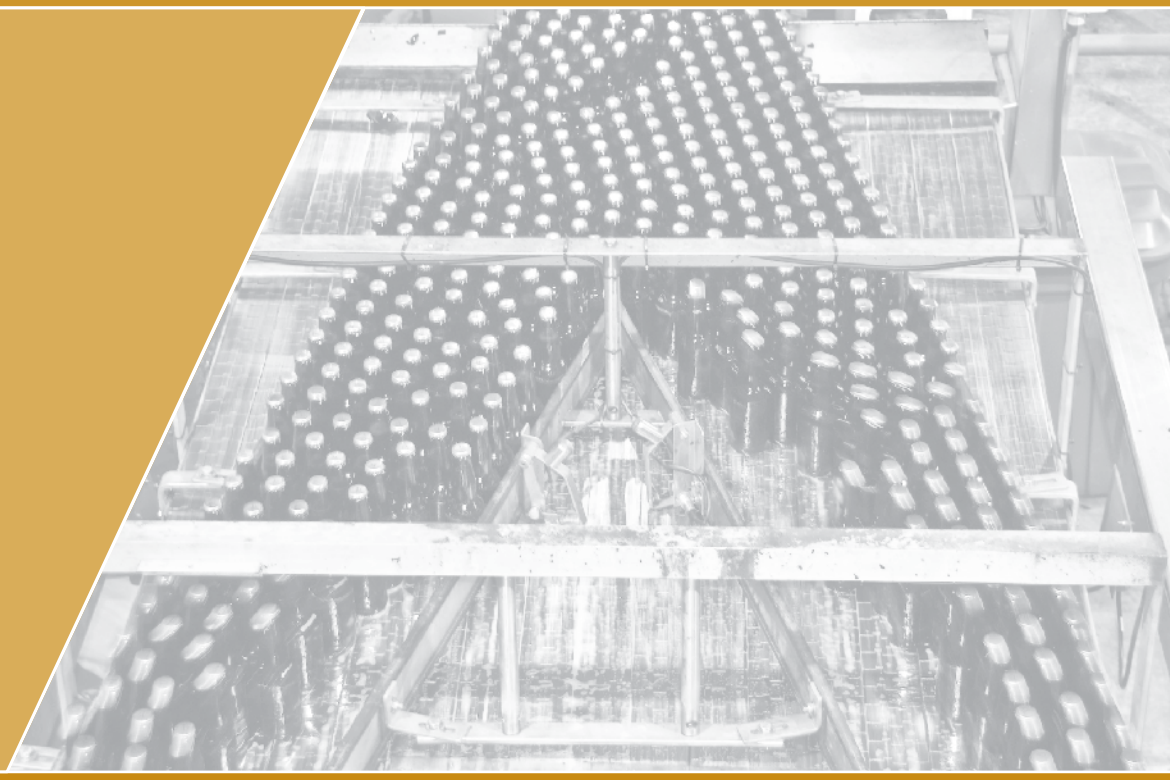
Capturing this expertise should be considered before valued, experienced professionals retire from the brewery. Expert computerized control systems coordinate and optimize process operations. They are not yet extensively used but are commercially available. Examples of the applications include refrigeration and manufacturing controls especially linked to the use of brewery utilities. Their deployment in the monitoring and targeting system puts utility resource management on par with the management of any other resource in the brewery.

Replacement of PLC by PC process control

Many individual programmable logic controllers (PLC) may have been replaced by fully integrated personal computer (PC) process control packages. The user profits from consistent, repeatable process control that eliminates programming of individual PLCs and integrates operations. Process changes can be executed simply from the PC, even remotely; records and past history are archived; motors can be turned on and off in response to pre-programmed material and product flows, levels, pressures, etc. Various packages such as PCbrew™, PCflow™ and PCprocess™ have been made available. Their application in such areas as the boilerhouse, refrigeration, and packaging can assist energy saving efforts in the brewery.

8

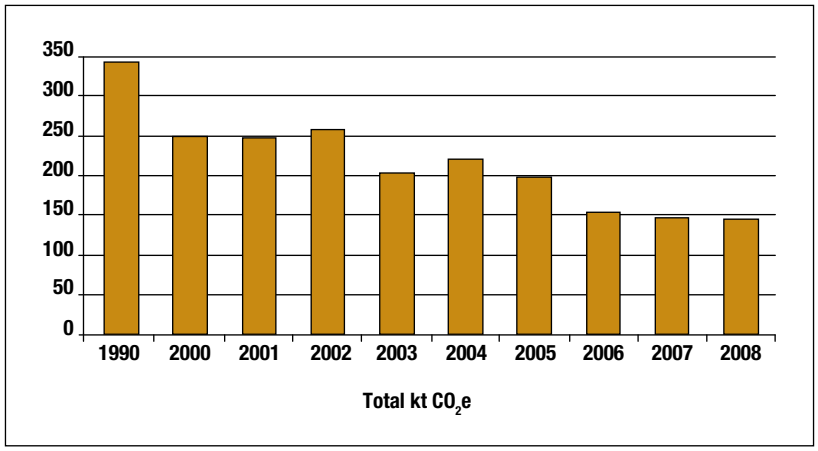
BREWERY EMISSIONS AND CLIMATE CHANGE



8.0 BREWERY EMISSIONS AND CLIMATE CHANGE

The Canadian brewing industry annually generates an extremely small fraction of Canada's total carbon dioxide emissions which is a chief contributor of greenhouse gases (GHG) related to climate change. In 2008, the sector produced 140 000 tonnes of the CO_2 e[3], which is a substantial improvement from the 1990 baseline when total emissions stood at 340 000 tonnes of CO_2e (Figure 8-1).

Figure 8-1: Total CO_2e emissions in Canadian brewing industry

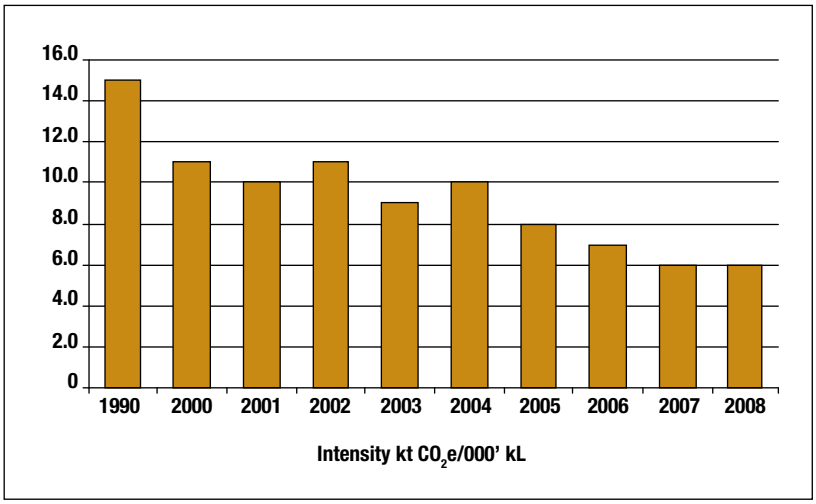


Breweries can help Canada reach its reduction objective by improving the energy efficiency in their operations.

The drop in the volume of beer produced in the period 1990 to 2008 (from 23.66 million hl to 22.56 million hl in 2008), coincides with a similar drop in CO_2e intensity (Figure 8-2).

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

Figure 8-2: CO_2e intensity in Canadian brewing industry



The CO_2e index also dropped from the base index 1.00 in 1990 down to 0.40 in 2008 – a 60-percent decrease. This is supported by a 2009 corporate environmental report from Molson Coors Canada, which indicated a 13-percent drop of CO_2e emissions between 2006 and 2007 in Canadian brewing operations.

However, more needs to be done in our breweries to further reduce energy consumption in all its forms. Improved energy efficiency reduces greenhouse gas emissions in two ways:

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

For an example of how to calculate the amount of reductions in major greenhouse gases emissions resulting from energy efficiency projects undertaken in your brewery, refer to Appendix 9.3 – Calculations of emission reductions. Additional treatment of the topic is in Section 7.3.2 – Environmental impact of boiler combustion.

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

8.1 CALCULATING ONE'S CARBON FOOTPRINT

An offshoot of the concerns with climate change has been an effort to manage carbon dioxide emissions globally by emissions trading. Emissions trading, also known as cap and trade, is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. In a cap-and-trade system, a government body gives corporations "allowances" that limit the amount of pollutant (greenhouse gases and air pollutants) they can emit. Companies that reduce their emissions below their limit or cap have "surplus" allowances or credits they can either sell or bank for future use.

For economic reasons as well as environmental reasons, it is desirable to know the amount of emissions produced by the company and its impact on the environment or carbon footprint. Determining a carbon footprint is a new business in which many companies are now involved. The Internet has many references to various sites which provide information on how to calculate one's footprint such as www.carbonfootprint.com/calculator.aspx or www.nature.org/initiatives/climatechange/calculator/.

Calculating a brewery's carbon footprint is rather simple. It is necessary to know the annual consumption of energy in all its forms (electricity, natural gas, LPG, fuel oil by type, propane, diesel fuel and gasoline for emergency power generators, lift trucks, trucks and cars the brewery operates). Even the average fuel consumption of staff cars and trucks, total mileage driven while distributing product whether on business trips by car or airplane. Using the emissions converter (some of the equivalents are shown in the tables in Appendix 9.3), one calculates the total emissions as metric tonnes (t) of carbon dioxide equivalents, CO_2e, and summarizes them.

Table 8-1 demonstrates the relationships in calculating the Global Warming Potential (GWP) of the emissions. The relationship, as well as the simple calculation formula involved (shown below), can be used with advantage when an energy use reduction project is contemplated in the brewery (e.g. in a burner retrofit project for the boilers).

Table 8-1: Global Warming Potential (GWP) of the emissions

Baseline emissions		GHG		CDM project emissions		Net reduction		GWP[a]		$C0_2e$[b]
0	–	$C0_2$	–	0	=		x	1	=	
0	–	CH_4	–	0	=		x	21	=	
0	–	N_20	–	0	=		x	310	=	
0	–	HFC-23	–	0	=		x	11700	=	
0	–	HFC-125	–	0	=		x	2800	=	
0	–	HFC-134a	–	0	=		x	1300	=	
0	–	HFC-152a	–	0	=		x	140	=	
0	–	CF_4	–	0	=		x	6500	=	
0	–	C_2F_6	–	0	=		x	9200	=	
0	–	SF_6	–	0	=		x	23900	=	
0		**Totals**		0						
								Grand total		

a Global Warming Potential as related to CO_2.

b Carbon dioxide equivalent.

Source: BAC/CO_2 Equivalent Calculator (Beta), adopted

Note: All units should be converted to metric tonnes before keyed into the calculator. You only need to provide values for the Baseline Emissions and CDM Project Emissions columns. Indicate 0 (zero) for empty fields. To avoid errors, make sure to hit all the Calculate buttons before hitting Total.

This type of calculation backed up by flue gas analyses, enabled, for example, Great Western Brewing Company, to demonstrate that the comprehensive review of boilers, particularly the retrofitting of the burners, brought the NO_x emissions down to California standards.

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

Energy equivalency in CO_2:

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

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

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

8.2 INTERNATIONAL CARBON FOOTPRINT CALCULATIONS

There is little data available on carbon footprint for beer brands. Additionally, it is difficult to compare existing data because of lack of a carbon footprinting standard. The UK PAS2050 standard, now in draft stage, may become the international standard for carbon footprinting. A comparison of data published in corporate reports for international brewers shows the carbon footprint – as kg CO_2e per hl – for Asahi 10.5, Fosters 14; Heineken 10.5; InBev 13; Grupo Modelo <16; SAB-Miller >12. However, the New Belgium Brewing Company's analysis showed the total carbon footprint (using their main, Fat Tire brand) – as kg CO_2e per hl – of 27.9 for malt production and transport; 5.8 for brewing process; 40 for packaging materials (of which 32.3 was accounted for by glass production); 12.9 for distribution; 12.3 for storage in the outlet; and 2.4 for waste disposal.[4]

[4] *The Institute of Brewing and Distilling (IBD), Master Brewers Association of the Americans (MBAA) Energy Benchmarking Survey, Carbon Footprinting and Life Cycle Analysis report by Gordon Jackson et al.,*

9

APPENDICES

9.0 APPENDICES

9.1 GLOSSARY OF TERMS AND ACRONYMS

Only some of the terms used in the preceding text are explained here. For others, please view dictionaries, textbooks, professional literature or encyclopedias.

Aerobic	Conditions in which air (oxygen) is present.
Anaerobic	Conditions in which there is no oxygen present.
Barm beer	Also called rest beer. The beer that remains within the mass of harvested yeast (usually high-gravity, high-alcohol beer) and which centrifugation or filtration may recover.
Blowdown	The maintenance of Total Dissolved Solids content in boiler water by draining small quantities either continually or intermittently from the base of the boiler to remove accumulated solids.
BOD	Biological oxygen demand. The standard test carried out at 20°C over five days, for the measurement of water pollution in terms of the quantity of dissolved oxygen (mg/L) needed by microorganisms to break down biodegradable constituents in the waste water.
Carbon footprint	Environmental impact of operations on the generation of greenhouse gases (GHG), expressed as carbon dioxide equivalent (CO_2e).
CCA	Capital cost allowances.
CIP	Cleaning-in-place of brewing vessels, mains, road tankers, etc.
COD	Chemical oxygen demand. The measure of oxygen consumption, in mg/L, as supplied by hot acidified potassium dichromate, required to oxidize waste water components. It is always higher than BOD_5, which, for brewery waste water, is about 60 to 70 percent of COD.
Condensate	Water produced by condensation of steam.
Condensing boiler	A boiler in which the water vapour produced by combustion is condensed to provide additional heat to the incoming water.
Dew point	The temperature at which air becomes saturated with water vapour and moisture starts to condense at a given pressure.
EAC	Energy-accountable centre, particularly in the context of Monitoring & Targeting methodology.

Economizer	A heat exchanger that recovers energy from flue gas.
Emission	(in this context) Pollution at the point of discharge.
Emissions Trading (also known as cap and trade)	A market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants.
EMO	Energy management opportunity, to save or conserve energy. The term is frequently used in this Guide.
EMS	Energy Management System. The part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.
EMT	Energy management team.
GHG	Greenhouse gases – gases emitted by operations – that are implicated in global warming.
GWP	Global Warming Potential (of various types of emission, all relating to CO_2e); the GWP of carbon dioxide, CO_2 = 1.0.
HCV	Higher calorific value. The energy released from burning unit mass of fuel and when the resulting flue gas is condensed (also, gross calorific value or higher heating value).
High-gravity brewing	The practice of producing and fermenting wort at a higher concentration of dissolved solids (i.e. high gravity) than is required to package. The original gravity is adjusted by dilution with carbonated water prior to packaging, usually at the final filtration stage.
LCV	Lower calorific value. The energy released when unit mass of a fuel is burned and the flue gas is not condensed (also, net calorific value or lower heating value).
Make-up water	Water added to a boiler to replace condensate losses.
Mashing	The process of enzymatic hydrolysis that, upon mixing the malt grist with water and heating it following a pre-set program, converts malt starch into soluble sugars, producing (sweet) wort.
Maturation	Also called "aging." Process of developing and stabilizing beer flavour, and of beer conditioning.
Modular boiler	A boiler that may be combined with others of the same type supplying a common system. The number of boilers in use at any time depends on the demand load.

NAICS	North American Industry Classification System; each industry type has a discreet, assigned code.
Natural gas	Mostly methane, largely unprocessed earth gas.
Oxygen trim	A device that senses the oxygen content in the flue gas and controls the air-to-fuel ratio. Sometimes combined into a combustion efficiency monitor.
Pasteurization	The process of heating beer to destroy or inactivate micro-organisms capable of growing in it.
PDCA	The abbreviation of the words Plan-Do-Check-Act, the principle of continual improvement, pioneered by Dr. Edward Deming.
Peak demand	The maximum demand of electricity that occurs in a timed period, e.g. 15 or 30 minutes. A public utility may restrict this charge to certain times of the year (e.g. winter months) when the demand on distribution is at its peak. An integrating meter that sums up the consumption, records the maximum value and then resets to zero during every set period measures peak demand.
Power factor	The cosine of the phase angle between potential (volts) and current (amperes). Public utilities charge customers a cost penalty if the power factor is lower than a specified value, e.g. 0.93, since difficulties arise in supply and distribution systems if the power factor is significantly lower than unity.
Residual beer	Beer lost through various processes.
ROI	Return on investment.
Saturated steam (saturated water)	Steam or water at its saturation temperature.
Saturation temperature	The temperature at which water will evaporate or steam will condense, at a given pressure.
Sparging	Washing out of extract remaining in the spent grains by spraying water over it in the lauter tun.
SEC	Specific energy consumption; usually in MJ/hl.
SWC	Specific water consumption; in hl water to hl beer ratio.
Superheated steam	Steam at a temperature higher than the saturation temperature.
SS	Suspended solids. Solids that can be separated by filtration through a membrane.
VSD	Variable speed drive. A device to modulate the speed of the compressor to enable its “soft” starts, reduce demand spikes in electricity, and flexibly respond to compressed air demand.

9.2 ENERGY UNITS AND CONVERSION FACTORS

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

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

0°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.

Multiples:

10^1	deca	(**da**)
10^2	hecto	(**h**)
10^3	kilo	(**k**)
10^6	mega	(**M**)
10^9	giga	(**G**)
10^{12}	tera	(**T**)
10^{15}	peta	(**P**)

Fractions:

10^{-1}	deci	(**d**)
10^{-2}	centi	(**c**)
10^{-3}	milli	(**m**)
10^{-6}	micro	(**μ**)
10^{-9}	nano	(**n**)

Derived SI units:

Volume:	hectolitre	(**hl**)	100 L
	cubic metre	(**m³**)	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/m²
	U value		Watt/m²K
	Thermal conductivity		W/mK
Pressure:	Pascal	(**Pa**)	

Conversion factors:

	Multiply	by	to obtain
Length	metre	3.2808399	feet
	metre	39.370079	inches
Mass	kg	2.2046226	pounds
	tonne (t)	0.9842206	tons (long)
	tonne (t)	1.10233113	tons (short)
Volume	L	0.219975	gallons (Imperial)
	L	0.264173	gallons (US)
	L	0.035315	cubic feet
Energy			
Quantity of heat	kWh	3.6	MJ
	kWh	3412	BTU
	MJ	947.8	BTU
	BTU	0.001055	MJ
Heat emission or gain	W/m^2	0.317	BTU/ft^2
Specific heat	kJ/kgK	0.2388	BTU/lb.°F
Heat flow rate	W	3.412	BTU/h
U value, heat transfer coefficient	W/m^2K	0.1761	$BTU/ft^2h°F$
Conductivity	W/m K	6.933	BTU $in/ft^2h°F$
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	9869	std. atmosphere
	mm Hg (mercury)	133.332	Pa
	ft of water	2.98898	kPa
Specific volume	m^3/kg	16.02	ft^3/lb.
Velocity	m/s	3.281	ft/s

Useful values:

1 Therm	=	100 000 Btu	or	29.31 kWh
1 ft^3 of natural gas	=	1 000 Btu	or	0.2931 kWh
1 US gal #2 oil	=	140 000 Btu	or	41.03 kWh
1 Imp. gal #2 oil	=	168 130 Btu	or	49.27 kWh
1 US gal #4 oil	=	144 000 Btu	or	42.20 kWh
1 Imp. gal #4 oil	=	172 930 Btu	or	50.68 kWh
1 US gal #6 oil	=	152 000 Btu	or	44.55 kWh
1 Imp. gal #6 oil	=	182 540 Btu	or	53.50 kWh
1 boiler horsepower	=	33 480 Btu/h	or	9.812 kW
1 mechanical HP	=	2 545 Btu/h	or	0.7459 kW
1 ton refrigeration	=	12 000 Btu	or	3.5172 kWh
1 beer barrel U.K.	=	1.6366 hl		
1 beer barrel Canadian	=	1.1365 hl		
1 beer barrel US	=	1.1735 hl		
1 MJ	=	0.278 kW/h		
1 kcal	=	4.18 J		
1 kWh	=	1.168 Mcal		

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

"Rule-of-thumb" conversion – use for quick illustration in propagating the energy conservation efforts in your plant:

1.0 MJ equals
- the energy content of about one cubic foot of natural gas, or
- the energy consumed by one ordinary incandescent 100 Watt bulb burning for almost three hours, or
- one horsepower electric motor running for about 20 minutes.

To convert kBtu/USbarrel to kWh/hl, use the conversion factor 0.25 kWh/hl/kBtu/barrel.

To convert kBtu/USbarrel to GJ/hl, use the conversion factor 0.0009 GJ/hl/kBtu/barrel.

Grid electricity – consider greenhouse gas emissions generation on the average as **1 kg CO_2e/kWh**

9.3 CALCULATING REDUCTIONS IN GREENHOUSE GAS (GHG) EMISSIONS IN BREWERIES

Although the following examples may seem specialized, the method used to calculate emission reductions applies to any energy management project that reduces consumption of fuel or electricity.

Exercise: Calculate emissions for on-site combustion systems

In a large brewery, the original natural gas burners in the boilers were retrofitted with high-efficiency burners. Annual fuel savings are estimated at 5 terajoules (TJ).

What would be the corresponding reductions in CO_2, CH_4 and NO_x emissions? Use the data in Table 9-1 and the information given below to calculate the amount of CO_2, CH_4 and NO_x produced by combustion systems. To perform this calculation for your own facilities, obtain precise data from your natural gas utility.

The emission factors for natural gas are CO_2: 49.68 t/TJ; CH_4: 0.13-1.27 kg/TJ; NO_x: 0.62 kg/TJ. A range of 0.13-1.27 kg/TJ has been indicated for CH_4, so we will assume 0.6 kg/TJ for this calculation.

CO_2 reduction
= 5 TJ/yr x 49.68 t CO_2/TJ
= 248.4 t/yr

CH_4 reduction
= 5 TJ/yr x 0.6 kg CH_4/TJ
= 3 kg/yr

NO_x reduction
= 5 TJ/yr x 0.62 kg NO_2/TJ
= 3.1 kg/yr

Table 9-1: Greenhouse gas emission factors by combustion source

Fuel type	CO_2		CH_4		NO_x	
Gaseous fuels	**t/ML**	**t/TJ**	**kg/GL**	**kg/TJ**	**kg/ML**	**kg/TJ**
Natural gas	1.88	49.68	4.8-48	0.13-1.27	0.02	0.62
Still gas	2.07	49.68	–	–	0.02	0.62
Coke oven gas	1.60	86.00	–	–	–	–
Liquid fuels	**t/kL**	**t/TJ**	**kg/kL**	**kg/TJ**	**kg/kL**	**kg/TJ**
Motor gasoline	2.36	67.98	0.24-4.20	6.92-121.11	0.23-1.65	6.6-47.6
LPGs	1.11-1.76	59.84-61.38	0.03	1.18	0.23	9.00-12.50

Fuel type	CO_2		CH_4		NO_x	
Diesel oil	2.73	70.69	0.06-0.25	1.32-5.7	0.13-0.40	3.36-10.34
Light oil	2.83	73.11	0.01-0.21	0.16-5.53	0.13-0.40	3.36-10.34
Heavy oil	3.09	74.00	0.03-0.12	0.72-2.88	0.13-0.40	3.11-9.59
Petroleum coke	4.24	100.10	0.02	0.38	–	–
Solid fuels	**t/t**	**t/TJ**	**g/kg**	**kg/TJ**	**g/kg**	**kg/TJ**
Anthracite	2.39	86.20	0.02	varies	0.1-2.11	varies
CDN bituminous	1.70-2.52	94.3-83.0	0.02	varies	0.1-2.11	varies
Sub-bituminous	1.74	94.30	0.02	varies	0.1-2.11	varies
Lignite	1.34-1.52	93.8-95.0	0.02	varies	0.1-2.11	varies
Coke	2.48	86.00	–	–	–	–
Fuel wood	1.47	81.47	0.15-0.5	0.01-0.03	0.16	8.89

Abbreviations: t = tonne; kg = kilogram; g = gram; ML = megalitre; TJ = terajoule; kL = kilolitre; GL = gigalitre.
(See Appendix 9.2: Energy units and conversion factors.)

Source: *Voluntary Challenge and Registry Program Participant's Handbook*, August 1995, and its addendum, issued in March 1996. Data supplied by Environment Canada.

Exercise: Calculate the impact of reductions in electrical consumption

Energy management projects that reduce electricity consumption have a positive effect on the environment. However, the emission reductions occur at the electrical generating station rather than at the site of the efficiency improvements. To calculate the emission reduction, use the method shown above, and then calculate the energy saved at the generating station. This is done by adjusting the figure representing energy saved at the site to account for losses in the electrical distribution system.

At a large manufacturing plant in Saskatchewan, fluorescent light fixtures were replaced by metal halide fixtures and several large electric motors were replaced with high-efficiency motors. The total annual energy saving was 33 600 MWh. Table 9-2 and the information given below was used to calculate the corresponding reduction in GHG emissions. To perform this calculation for your facilities you should obtain precise data from your public utility.

Table 9-2 shows that, in Saskatchewan, the average CO_2 emission from electrical power generation is 0.82 t/MWh. Convert to equivalent energy saving at the generating station using a transmission efficiency of 96 percent.

Annual energy savings at generating station:
= 33 600 MWh : 0.96 = 35 000 MWh/yr

CO_2 reduction:
= 35 000 MWh/yr x 0.82 t/MWh
= 28 700 t/yr

Table 9-2: Average CO_2 emissions for 1998, by unit of electricity provided

	t/MWh	t/TJ
Atlantic Provinces	0.25	68.4
Quebec	0.01	2.5
Ontario	0.23	65.2
Manitoba	0.03	8.2
Saskatchewan	0.83	231.7
Alberta	0.91	252.1
British Columbia	0.03	7.4
Northwest and Yukon Territories	0.35	98.5
Canada Average	0.22	61.3

Source: 1996 survey of utilities by the Demand Policy and Analysis Division, Office of Energy Efficiency, Natural Resources Canada

9.4 ENERGY EFFICIENCY OPPORTUNITIES SELF-ASSESSMENT CHECKLIST

The following is a list of sample questions to answer when establishing the current status in your brewery.

More questions may be formulated from the EMOs in the preceding sections.

Use the following audit questions as a guide (mark an "X" in the box if an action is required).

Management

- ❑ Does the brewery have an energy policy? Are all employees aware of it?
- ❑ Does the brewery have an energy 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 results of energy and utilities conservation efforts to employees?

Electricity power demand

- ❑ Is the load profile known?
- ❑ If not, has the local utility or a consultant been contacted for help?
- ❑ Is there a system in place to prevent the load from exceeding a given value during peak billing hours?
- ❑ Can equipment presently being run during peak demand periods be re-scheduled to off-peak times or to other peak times when load is low?
- ❑ Can some non-essential equipment be shut off during peak demand periods by use of timers or production operators?

Consumption

- ❑ Is there a procedure to shut off production equipment and auxiliary production equipment when not in use?
- ❑ Has it been implemented?

Power factor

- ❑ Is the power factor, as noted on the electrical bills, less than 90 percent?
- ❑ Is there a billing penalty for poor power factor?
- ❑ If so, do you monitor how much it costs you?
- ❑ Have you considered means and equipment to improve the power factor?

Fuels

- ❑ Would it be possible to use a cheaper alternative source for thermal energy?
- ❑ If natural gas is used, have the costs of uninterruptible versus interruptible supply been evaluated?

Fuels/material storage

- ❑ Is heating in the area controlled and is temperature being maintained at the minimum acceptable level for a raw material store?
- ❑ Are the cold storage rooms adequately insulated and the doors well sealed to minimize heat loss?
- ❑ Is the passageway to cold storage areas fitted with flexible aprons to isolate it from warmer areas?
- ❑ Are heated oil tanks and associated piping adequately insulated?
- ❑ Is the oil heated at the correct temperature?
- ❑ Are the outside syrup (if used) storage tanks and associated piping adequately insulated?
- ❑ Is the external insulation watertight?

Boilers and steam distribution

- ❑ Is boiler efficiency checked on a 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 steam demand matched to boiler deployment done on weekends and in non-production periods?
- ❑ Are the flue gases checked for CO_2 and oxygen content on regular basis? Are they within an acceptable range?
- ❑ What is the flue gas temperature?
- ❑ Is a flue gas heat recovery system being used?
- ❑ Is there any evidence of soot buildup on the boiler's fireside surface?
- ❑ 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? At what intervals?
- ❑ What is the blowdown rate and is it at the level recommended by water treatment specialists?
- ❑ Is it based on the dissolved solids content of the boiler water?
- ❑ Has the dissolved solids content been calibrated to conductivity?
- ❑ Is there a system in place to recover heat from the blowdown?
- ❑ Is waste oil from process equipment burned in the boiler?
- ❑ Is there redundant or oversized steam piping causing excessive heat loss?
- ❑ Are steam lines, flanges, valves, condensate lines, etc. adequately insulated?
- ❑ Is there evidence of steam or condensate leaks?
- ❑ Is the condensate return rate adequate and is it being verified?
- ❑ Are steam traps the correct type for the application being used?
- ❑ Is there an adequate maintenance program for the inspection, repair and replacement of steam traps?
- ❑ What percentage of traps is found to be faulty?
- ❑ Is there a program in place to remove scale from heat transfer surfaces of equipment?

Cooling water

- ❑ Are there opportunities to reduce the quantity of cooling water being used?
- ❑ Is a 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 reused 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 reusing process water been examined from the point of view of double or multiple reuse?
- ❑ Have all processes been evaluated for such reuse?
- ❑ In cleaning operations, is low-pressure, high-volume hosing down used instead of the other way around where it is possible?
- ❑ Is high-pressure, small-volume sluicing of the whirlpool trubs practiced?
- ❑ Are hoses left running in the cellars, wasting water and adding to the refrigeration load?
- ❑ Is the post-filler water spray station tied in with the filler operation?
- ❑ Are eye showers left running as a source for cool drinking water?
- ❑ Is any hot water being put to the drain?
- ❑ Are there any quantities of perfectly usable water being dumped?

Compressed air

- ❑ Are there any opportunities to reduce or eliminate compressed air use in any of the processes?
- ❑ Is it possible to replace any compressed air-operated components with hydraulic or electric linear power?
- ❑ 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 is the method 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 frequently iced-up?
- ❑ Are there de-stratification fans in high-ceilinged refrigerated areas?

CO_2 collection and use

- ❑ What is the brewery's CO_2 balance: purchase vs. generation?
- ❑ What is the usage pattern? Is the usage metered and known?
- ❑ What governs CO_2 collection from the fermenters?
- ❑ How well controlled is the carbonization of beer and dilution water?
- ❑ Are there many instances of beer or dilution water reprocessing/dumping?
- ❑ Is alkaline solution-based cleaning done in the CO_2 atmosphere?

Emissions

- ❑ Have you performed carbon footprinting of your operations?
- ❑ Are you aware of the values, their financial price and have you considered them for emission trading?

Electric motors

- ❑ Is there a policy to replace old motors with energy-efficient (high-efficiency) motors?
- ❑ Is there a policy to replace smaller motors with energy-efficient motors?
- ❑ Is a rewind versus replacement evaluation made when motors fail?
- ❑ Are there any motors running at less than 50 percent of their rated capacity?
- ❑ Are motors checked for hot spots (bearings, contacts in connection boxes, etc.)?

Brewery envelope

- ❑ Is the wall insulation adequate? Is there evidence of frost or condensation on the inside of external walls?
- ❑ Is the roof insulation adequate? (Snow melts quickly on a poorly insulated roof.)
- ❑ Has a thermograph analysis of the building envelope (and of the process insulation) for potential heat loss locations been considered?
- ❑ Are windows single glazed? Is there broken/cracked glass?
- ❑ Are there gaps between the walls and window frames?
- ❑ Are east, south or west-facing office windows using reflective glass or fitted with reflective foil or with shades?
- ❑ Are external doors being left open for "ventilation"?
- ❑ Are the employees aware that such a practice negates air conditioning throughout the year?
- ❑ Are external doors free from drafts when closed?
- ❑ Are frequently used doors (such as the main entrance) designed to minimize air movement in and out of the building?
- ❑ Are doors at loading docks fitted with dock seals?

HVAC

- ❑ Is HVAC equipment shut down when buildings are unoccupied?
- ❑ Has the use of a central computerized HVAC and lighting management system been considered?
- ❑ Are thermostats used to control building temperatures and are the temperature settings appropriate for the type of work being carried out?
- ❑ Are setback temperatures used when buildings are unoccupied?
- ❑ Are thermostats tamper-proof?
- ❑ Are paint booths, soakers, and carton shredders fitted with exhaust fans?
- ❑ Is the fan use coupled with the equipment use?
- ❑ Is the balance between intake and exhaust air satisfactory?
- ❑ How do you know?
- ❑ Is the volume of fresh air intake excessive?
- ❑ Is there a way to reduce levels when the production is stopped or working at lower levels?
- ❑ Is there any problem with stratification, particularly in winter?
- ❑ Has the use of ceiling fans for air circulation been considered?
- ❑ Can any process heat or exhaust heat be recovered to heat incoming fresh air?
- ❑ Is there a cheaper alternative energy source for heating?

Lighting

- ❑ Are lights left on when not needed?
- ❑ Do observations during non-working times need to be made?
- ❑ Are there areas that are overlit?
- ❑ Are there areas that are underlit?
- ❑ Are dimmers used to match lighting levels to the task being performed?
- ❑ Is lighting switched off when the building, storage areas, offices, etc., are unoccupied?
- ❑ Have motion sensor switches been considered?
- ❑ Can outside security lighting be controlled by motion sensors?
- ❑ Are lights clean?
- ❑ When ordering replacement bulbs, are the most energy-efficient bulbs specified?
- ❑ Do you know what the energy-efficient types are?
- ❑ Can any of the lighting systems be replaced with more energy-efficient systems?

Mill room

- ❑ Are dust extraction systems fitted with variable drives? (Ask this question for any other motor-driven equipment.)
- ❑ Are the dust collectors inspected/cleaned regularly?
- ❑ Is steam used only when conditioning malt (if used for that)? Any leakage?
- ❑ Is the setting of grist mills and malt grist composition checked regularly?
- ❑ Are the mill rollers inspected and re-grooved regularly?

Brewhouse

- ❑ Is there adequate ventilation of the brewhouse in the summer?
- ❑ Has the installation of a kettle stack economizer been considered?
- ❑ Has the hot water been balanced for the entire brewery?
- ❑ If a stack scrubber for odour control is being used, is the spray water recycled?
- ❑ Is there an effective program for cleaning scrubber fill (saddles)?

Wort cooling

- ❑ Are the heat exchange surfaces de-scaled frequently enough?
- ❑ How often is the heat exchanger taken apart and inspected?
- ❑ Has heat reclamation from the wort cooler been considered?

Fermenting and yeast room

- ❑ Is CO_2–removing ventilation in the fermenting room tied to actual CO_2 readings to prevent excessive evacuation, especially in the summer?
- ❑ Is water use for tank flushing and floor rinsing minimized?
- ❑ Is the refrigeration equipment ice-free?
- ❑ Is the use of stirrers in the yeast tanks intermittent?

Aging and finished beer cellars

- ❑ Is the cellar's ambient temperature checked regularly?
- ❑ Are the cellars well insulated?
- ❑ Is outside air infiltration prevented, especially in the summer?
- ❑ Conversely, could outside low temperatures be taken advantage of in the winter?
- ❑ Is beer cooling excessive?
- ❑ Is the use of water for floor rinsing minimized?
- ❑ Are stationary beer pumps in the packaging cellar insulated for sound and heat?

Packaging department

- ❑ Is it possible to reorganize operations by moving product packaging from less efficient lines to more efficient lines in order to shut down a complete line?
- ❑ Is the operation of conveyors linked to the operation of the filler?
- ❑ Has the optimal pasteurization (number of P.U.) been determined?

Warehouse, shipping and receiving

- ❑ Is heating in the area controlled and is the temperature being maintained at the minimum acceptable level?
- ❑ Are air seals (curtains, aprons) used around truck loading doors?
- ❑ Are measures in place to prevent ingress of ambient heat from packaging areas into refrigerated areas?
- ❑ Are loading doors closed when not in use?
- ❑ Can lighting levels be reduced?

- ❑ Is high-efficiency lighting being used?
- ❑ If electric forklift trucks are being used, are batteries charged in off-peak times?

By-products

- ❑ How is the waste beer collected and disposed of? Is it eliminated from the wastewater stream?
- ❑ How is the spent diatomaceous earth ("filter aid") disposed of?
- ❑ Can it be segregated from the wastewater stream?

Solid waste

- ❑ Is the waste segregated by type (glass, cardboard, wood, etc.)?
- ❑ Are there separate collection containers available throughout the plant?
- ❑ Have employees been educated and trained about the issue?
- ❑ Could some solid waste types be given away (plastic barrels, firewood, contaminated glass for road building)?
- ❑ Could some be sold (crown boxes, uncontaminated glass cullet, aluminum cans, metal scrap)?
- ❑ Could some be recycled (work gloves, protective clothing)?
- ❑ Has the use of a compactor been evaluated?
- ❑ Is the solid waste weighed on site before haul-away?
- ❑ Has the current waste disposal contract been competitively evaluated?

Wastewater and treatment

- ❑ Has there been a review of the separate wastewater streams to quantify their loading with a view to reduce or eliminate contamination at the source?
- ❑ Has there been a review of the history and trend of effluent surcharges?
- ❑ Is the wastewater combined stream metered? If not, has the formula for calculating it been reviewed? Does it include brewhouse evaporation?
- ❑ Is wastewater regularly sampled for pH?
- ❑ Have suspended solids and oxygen demand been evaluated?
- ❑ Have the results of municipal sampling been verified in the plant or through independent and certified laboratories?
- ❑ Has the use of surplus, non-liquefiable brewery CO_2 or flue gases been considered for pH control of the brewery effluent?
- ❑ If treated on site aerobically, is aeration efficient? Is it geared to BOD/COD loading, temperature?
- ❑ Have fine-bubble diffusion systems been evaluated?
- ❑ How is sludge disposed of?
- ❑ If treated anaerobically, can the methane gas be burned off in the boiler or used to preheat intake air?

Maintenance

- ❑ Is there a formalized preventive/predictive maintenance program in place?
- ❑ Are equipment checklists used for preventive maintenance?
- ❑ Is there good instrumentation to measure operating parameters (temperature, pressure, flow rates, compressed air losses, etc.)?

- ❑ Is the measuring and monitoring equipment regularly calibrated or its function otherwise verified?
- ❑ Are gauges calibrated on a regular basis?
- ❑ Is operation equipment fitted with automatic time and temperature controls?
- ❑ Is there sufficient instrumentation and recording equipment to enable employees to set up equipment correctly and to enable maintenance and engineering staff to troubleshoot?
- ❑ Are synthetic lubricants used in gearboxes, compressors, etc.?

9.5 "BEST PRACTICES" IN ENERGY EFFICIENCY AS VOLUNTEERED BY SMALL BREWERS

The list below provides tips and best practices in energy and utility savings as currently implemented by some small breweries. This is over and above the more detailed case studies found in the Guide. It is hoped that these examples and the case studies will motivate brewers to make such efforts to improve their energy efficiency.

Boilers/Steam

- The comprehensive review of boilers, particularly the retrofitting of the burners brought the NO_x emissions down to California standards.
- The examination of the steam plant standard operations resulted in operating it at a lower pressure, and the boilers were further optimized to in-plant use during brewhouse operations and after the brewing finished.
- Consider the separation of process and heating steam and condensate return systems so that heating loops can be isolated during non-heating periods.

Refrigeration

- The optimization of suction and discharge pressures resulted in substantial savings – currently being quantified.
- The use of Variable Speed Drives (VSD) for ammonia condensers for chilling optimized the power use.
- The energy efficiency measures in refrigeration resulted in 1.6 M kWh savings. Our discharge pressure is approximately 90 psi all winter, the set point based on wet bulb temperature. VSD and slide valve control result in optimum compressor efficiency and the VI ratio correction ensures we are not over-compressing.
- Use the heat rejected by your refrigeration system to heat your space, especially if you are in a cold climate. The refrigeration system has to work in the winter anyway, so the heat rejected can be "free" except for the capital investment. Not always an easy retrofit, but easy to do at start-up, and can be an option should equipment replacement or retrofit be necessary.
- When designing a plant or investing significant capital, cross cutting is a great opportunity. We use ammonia waste heat to preheat boiler feedwater and are looking at other opportunities to expand CO_2 from liquid to gas. This is easier done with new infrastructure but the opportunity is certainly there.

- Consider implementing an oil inventory management program in refrigeration to track the amount of oil added and drained from the system. We had an instance in the past where an oil separator was not doing its job and we were getting far too much oil carrying over to our process equipment.
- Incondensables represent a huge loss. A good way to check this is to measure the temperature of the discharge ammonia from the condenser at the bottom of the discharge elbow and then correlate that to a pressure and compare that to the head pressure you are running; the difference is what the non-condensable gas is adding.

Compressors – Air

- Compressed air leaks are a killer . . . As soon as you find one, try to find the time to perform the repairs as soon as possible.

Energy management/people issues

- For the small, large and medium-sized companies under one corporation, the integration of energy reduction targets with salaried staff was effective as an important means to improve engagement and address staff time considerations.
- It was suggested that it would be useful for a smaller brewer to pay attention to water and energy use and where losses are occurring, and that this would provide an important basis for taking action. However, the lack of baseline data could make it difficult to assess performance.
- Two small brewers noted, that for them, a lack of manpower presented a key challenge to an organized, systematic effort to improve energy efficiency.
- The importance of raising awareness was illustrated by a hugely successful employee contest to identify and fix leaks (compressed air, steam).

Lighting

- The use of natural lighting complemented by spot lights where required, as well as making use of outside weather for cooling and heating, provides savings.

Water

- By improving the water balance in the brewhouse, we were able to use "saved" hot water to supply the 10 percent of water used for flushing. We expect this will result in a savings in the steam which is required to heat up cold water. This will also reduce the use of make-up water.
- Our keg washing system utilizes a recirculation tank with a strength meter that allows us to reuse a cleaning solution over and over until the metered strength falls below an established threshold.
- One of the most important ways in which we conserve energy at our brewery is through heat regeneration in the cooling of our wort. The hot wort is passed through a heat exchanger that exchanges the heat with cold water that is used for cleaning, brewing and sterilizing.
- When cleaning multiple tanks we reuse the cleaning solution between more than one tank to reduce chemical usage and energy costs from hot water.
- Automated CIP, focus on chemical analysis (titration checks), led to reducing water consumption.
- Water reuse through recirculation and water recapture led to lowered water to beer ratio in the brewery – down to the 4.5:1 region.

Buildings/HVAC

- Put all exhaust fans on some kind of control, not a manual switch that can be left on. It can be a spring wound timer, a dehumidistat, or a thermostat – just something that will only allow the fans to run when needed.
- Don't bring in outdoor air when you don't need it and don't exhaust conditioned indoor air when you don't need to.
- Make the minimal investment in setback thermostats. Keep the office areas cool when not occupied (or warm in the summer) and keep the production area cool all the time to reduce heat loss to outdoors and heat loss from aging tanks to the space.
- Keep the heat in one place and the cold elsewhere. Keep all overhead doors well weather-stripped, including the keg fridge door, insulate all hot and cold piping and repair damaged sections promptly, maintain edge seals on dampers so that they close tightly.
- The brewing area is heated in the winter by the ambient heat given off by the brewing process.
- Letting climate work for you: opening up cellars to the outside in the winter for free cooling.
- Cooling with external air in winter was possible when the temperature gradient was at least 10°C.

Miscellaneous practices

- We are in the process of obtaining energy controllers that will capture and store energy from our systems during peak performance to be utilized later under less strenuous conditions.
- Recycle whenever and wherever you can. We wash dirty bottles in a bottle washer rather than use new ones, we use folding trays for bottles and cans rather than use glued/stapled trays so that we can refold them if they are in good shape, we have introduced a refillable beer filling system where people bring in a 1.9 litre jug and get it refilled over and over with draught beer (our customers love it).

9.6 SPECIFIC PRIMARY ENERGY SAVINGS AND ESTIMATED PAYBACKS

In Section 7, EMOs were divided into three categories, with an estimate of the investment intensity and payback period. The following tables list the energy savings and payback periods an energy or plant manager can expect from energy efficient measures undertaken in the brewery process in Table 9-3 or by improving the efficiency of utilities in Table 9-4. Although a bit dated, and related to U.S. conditions, these tables are still useful when contemplating one project over another as they demonstrate expected energy saving results of implemented improvements/reductions. The tables have been modified to show the effect of primary energy savings expressed in MJ/hl (instead of the original kBtu/barrel [US]).

Table 9-3: Primary energy savings and estimated paybacks for process-specific efficiency measures[5]

Process specific			
Process area	**Measure**	**Payback period in years**	**Primary energy savings[A] in MJ/hl**
Mashing and lauter tun	Waste heat recovery	n/a	Limited data
	Use of compression filter	2	17
Wort boiling and cooling	Vapour condenser	<2 to 5	<1-20
	Thermal vapour recompression	>2	14-16
	Mechanical vapour recompression	D	21
	Steinecker Merlin system	2	28
	High gravity brewing	<1	12-20
	Low pressure wort boiling	n/a	29-36
	Wort stripping	n/a	18-38
	Wort cooling	3	15
Fermentation	Immobilized yeast fermenter	n/a	Limited data
	Heat recovery	>2	Limited data
	New CO_2 recovery systems	>2	Limited data
Processing	Microfiltration	2 to 4	Limited data
	Membranes (alcohol-free)	4	17
	Heat recovery-pasteurization	n/a	1
	Flash pasteurization	n/a	5-13
Packaging	Heat recovery washing	<3	5
	Cleaning improvements	3.4	21

[A] Primary energy savings account for savings in fuel use, electricity use and electricity transmission and distribution losses. We use a conversion factor of 3.08 from final to primary electricity use, based on average U.S. power plant heat rates. Energy savings are primarily taken from data from case studies in the literature. To convert kBtu/US barrel to kWh/hl use the conversion factor 0.25 kWh/hl/kBtu/barrel. To convert kBtu/US barrel to GJ/hl, use the conversion factor 0.0009 GJ/hl/kBtu/barrel.

[5] Table found in the report "*Energy efficiency improvement and cost saving opportunities for breweries – an ENERGY STAR® Guide for energy and plant managers*", by C. Galitsky et al., Ernest Orlando Lawrence Berkeley National Laboratory and the U.S. Environmental Protection Agency, 2003.

Table 9-4: Specific primary energy savings and estimated paybacks for efficiency measures for utilities

Utilities			
Process area	**Measure**	**Payback period in years**	**Primary energy savings[A] in MJ/hl**
Boilers and steam distribution[B]	Maintenance	<1	4
	Improved process control	<1	3
	Flue gas heat recovery	>3	2
	Blowdown steam recovery	2.7	2-3
	Steam trap maintenance	<1	3
	Automatic steam trap monitoring	<1	<1
	Leak repair	<1	5
	Condensate return	>1	17-19
	Insulation of steam pipes	1	5-25
	Process integration	D	42-76
Motors and systems using motors[C]	Variable speed drives	2 to 3	5-22
	Downsizing	2	1-2
	High efficiency	1 to 2	1-2
Refrigeration and cooling[D]	Better matching of cooling capacity and cooling loads	3.6	1-2
	Improved operation of ammonia cooling system	5.5	<1-2
	Improved operations and maintenance	<1	4
	System modifications and improved design	≤3	5-7
	Insulation of cooling lines	n/a	Limited data

Utilities			
Process area	**Measure**	**Payback period in years**	**Primary energy savings[A] in MJ/hl**
Other utilities	Lighting	<2 to 3	2-5
	Reduce space heating demand	n/a	7
	Anaerobic waste water treatment	≤5	5-8
	Membrane filtration wastewater	<1 to 5	Limited data
	Control and monitoring systems	3.5	<1-33
	Combined heat and power (CHP)	4	60-90
	CHP with absorption cooling	5	71
	Engine driven chiller systems	2 to 4	11

[B] Based on data from two sources (EIA, 1997; Beer Institute, 2000), we assume an average U.S. brewery fuel usage of 212 kBtu/barrel (53 kWh/hl0, 90-100 percent of the fuel used in the boilers, and an average boiler conversion efficiency of 85 percent).

[C] We estimate a total plant electricity consumption of 122 kBtu/barrel (30.5 kWh/hl, or 110 MJ/hl), (EIA, 1997).

[D] Results vary widely, depending on plant configuration and size of the brewery.

n/a: Payback period for this measure could not be estimated from available data.

10

REFERENCES

10.0 REFERENCES

The following sources complemented the development of this guidebook and the use of information selected from them in the text is gratefully acknowledged. At the same time, the literature listed may serve as sources of additional or detailed information.

- *Energy Benchmarking Survey, Carbon Footprinting and Life Cycle Analysis*, Gordon Jackson et al., 2009 MBAA Convention paper (using also Brewer's Guardian of April 2009, 18-20, 30).
- *Implementing Carbon Management Strategy in a Major Brewery With Particular Reference to Developing Carbon Footprinting*; R. Heathcote ad R. Naylor, Monograph of the 35th Symposium of the European Brewery Convention on Environmental Sustainability, 2008.
- *Product Carbon Footprinting – Beer*; A. Fendler, Monograph of the 35th Symposium of the European Brewery Convention on Environmental Sustainability, 2008.
- *Brewing Greenly – The Barley and Hops Footprint*; J. Brooks, Modern Brewery Age Magazine, October 2008.
- The Brewers Association of Canada (BAC), production, fuel, energy, carbon dioxide (e) emissions and water use statistics, 2009.
- *Energy Consumption and Energy Intensity Indicators in Canadian Breweries*, 1990 to 2008, BAC, 2010.
- Fuel Consumption and Energy Intensity Indicators, 1990 to 2008, BAC, 2010.
- Greenhouse Gas Emissions and Greenhouse Gas Intensity Indicators, 1990 to 2008, BAC, 2010.
- Brewers of Canada – Microbrewery Benchmark Report, BAC, 2002.
- The Brewing Sector Task Force of the Canadian Industry Program for Energy Conservation (CIPEC), reports and statistics, extracted information, 2009.
- *Development of Energy Intensity Indicators for Canadian Industry 1990-2009*; The Canadian Industrial Energy End-use Data and Analysis Centre (CIEEDAC), Nyboer et al., Simon Fraser University; also 1997-2010 bulletins.
- *Energy Efficiency Opportunities in the Canadian Brewing Industry*; Lom & Associates Inc.; BAC, Natural Resources Canada, Office of Energy Efficiency and CIPEC, 1998.
- *CIPEC Energy Efficiency, Planning and Management Guide*, Lom & Associates Inc., CIPEC and NRCan, 2000.
- *Boilers and Heaters: Improving Energy Efficiency*; Lom & Associates Inc, Paul Dockrill and Frank Friedrich of CANMET; CIPEC and NRCan (OEE), 2000.
- *Energy Efficiency Improvement and Cost Saving Opportunities for Breweries – an ENERGY STAR® Guide for energy and plant managers*; C. Galitsky et al., Ernest Orlando Lawrence Berkeley National Laboratory and the U.S. Environmental Protection Agency, 2003.
- British Beer and Pub Association – Thirty years of Environmental Improvement (private communication).

- *Brewery Utilities – Manual of Good Practice*; European Brewery Convention, 1997.
- *Benchmarking for World-top Energy Efficiency*; Verification Bureau, 2006.
- *2007 Sustainability Report*; New Belgium Brewing Company.
- *Sustainable Winemaking in Ontario: Energy Best Practice for Wineries*; Wine Council of Ontario, 2006.
- *Team Up for Energy Savings – Lighting* (brochure); CIPEC, 2005.
- *Saving Energy with Tank Insulation*; Anon., Wine Business Online, Sept 15, 2003.
- Presenting an Energy Efficient Project to Management; Anon., Energy Matters, winter 2003, US Department of Energy.
- *Commercial Earth Energy Systems: A Buyer's Guide*; CanmetEnergy, NRCan, 2002.
- *Monitoring & Targeting at a Brewery*; Case Study # 273, Energy Efficiency Office, U.K., 1995.
- *Benchmarking Energy Efficiency World-wide in the Beer Industry 2003*; Brewing Research International (BRI) and KWA Business Consultants, report # 2308580DR02, 2004.
- *Cost Efficiencies in Brewing*; Brick Brewing Co. Ltd, OMAF, OCETA and NRI/IRAP, 2003.
- *Guidance Note for Establishing BAT in the Brewing Industry*; CMBC, 2002.
- *Energizing the Bottom Line with Energy Efficiency*; Annual Report; CIPEC and NRCan, 2009.
- *Best Practices in Japanese Food Industry – Brewing*; Hiroshi Kuroda, The Energy Conservation Center, Japan, 2007.
- Pasteurization Options for Breweries, Big Energy Project Innovation Workshop, by Industry, Tourism, and Resources Ministry of Australia, 2002.
- *Environmental, Health and Safety Guidelines for Breweries*; International Finance Corporation of World Bank Group, 2007.
- *New Belgium Brewery – Combined Heat and Power (CHP) generation*; Christine Brinker, 2004.
- *Chances and Barriers for Energy Service Companies? An Analysis for the German Brewery Sectors*; J. Schleich et al, Fraunhofer Institute for Systems and Innovation Research, 2001
- *Heineken Sustainability Report*; Heineken NV, 2008.
- *Sustainable Developments for the Brewing Industry*; F.R. Sharpe et al., Campden BRI and KWA Business Advisers, The Institute of Brewing and Distilling Africa Section, 2009 Convention proceedings.
- *Reducing Water and Effluent Costs in Breweries;* Good Practice Guide GG135, UK Environmental Agency, 1998.
- *Heads Up CIPEC* – Biweekly reports on achievements and innovation in Canadian Industry – to July, 2010, Office of Energy Efficiency, Natural Resources Canada.

- Success Stories, Canadian Industry Program for Energy Conservation, 2009.
- *Annual Report*; Canadian Industry Program for Energy Conservation, 2009.
- *The State of Energy Efficiency in Canada in 2008*; Office of Energy Efficiency, Natural Resources Canada.
- Statistics Canada, selected information, 2000-2008.
- *International Standards for Environmental Management Systems ISO 14001:2004 and ISO 14004:2004*; International Organization for Standardization, Geneva.
- *International Standards for Quality Management Systems ISO 9001:2008*; International Organization for Standardization, Geneva.
- *Energy Audit Programs – One Answer to Kyoto Protocol Commitments*; Finland, 2000.
- Excerpts from reports on various energy-using systems and novel brewery-related or brewery-usable practices, extracted from the International Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), made available through the Office of Energy Efficiency, Natural Resources Canada.
    - Compressed Air Leakage Reduction Using Electronic Condensate Drain Taps, U.K., 2000.
    - Compressed Air Savings Through Leakage Reduction and the Use of High Efficiency Nozzles, U.K., 2000.
    - The Performance of a Variable Speed Air Compressor, U.K., 2000.
    - Installation of a Chiller and of Rotary-drum Air Dryers, Canada, 2000.

References used in the First Edition of the Guide, some of which survived in this Second Edition:

- *Beer Pasteurization – Manual of Good Practice*; European Brewery Convention, 1995.
- *Best Practice Program, Good Practice Guide 30, Energy Efficient Operation of Industrial Boiler Plant*; Energy Efficiency Office, Department of Energy, UK, 1992.
- *Best Practice Program, Good Practice Guide 42, Industrial Refrigeration Plant: Energy Efficient Operation and Maintenance*; Energy Efficiency Office, Department of Energy, UK.
- *Best Practice Program, Good Practice Guide 126, Compressing Air Costs*; Energy Efficiency Office, Department of Energy, UK, 1991.
- *A Self-assessment Workbook for Small Manufacturers*; Rutgers University and Office of Industrial Technology, US Department of Energy, 1992.
- *Practical Brewery Hazard Analysis Critical Control Points*; L. Hargraves, The Brewer, 1996.
- *PC Control Versus PLC Control*; M. Coulter, Cemcorp Ltd., 1998.
- *Environmental Management in the Brewing Industry*; United Nations Environment Program (UNEP), 1996.

- *Inverter Speed Control Reduces Power Consumption of Electric Pumps at a Brewery*; CADDET, March 1992.
- *Refrigeration Fault Diagnosis System in Joshua Tetley Brewery*; U.K., Best Practice reports, Energy Efficiency Office, Ministry of the Environment, U.K., 1992.
- *Heads Up CIPEC – Focus on Breweries*; Office of Energy Efficiency, Natural Resources Canada, August 1999.
- *Intelligent Energy Management for Small Boiler Plants*; Gas Technology Canada, Canada Centre for Mineral & Energy Technology, March 1998.
- Analysis reports by the international Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), made available through the Office of Energy Efficiency, Natural Resources Canada:
    - Small Scale Cogeneration, 1995
    - Process Heating in the Metals Industry, 1993
    - Process Heating in the Low and Medium Temperature Ranges, 1997
    - Industrial Heat Pumps, 1997
    - Compact Heat Exchangers, 1999
    - Industrial Electric Motor Drive Systems, 1998
    - Low-NO_x Technology Assessment and Cost/benefits Analysis, Federal Industrial Boiler Program, Canada Centre for Mineral & Energy Technology, October 1994
- Tips for Energy Managers; Office of Energy Efficiency, Natural Resources Canada, 1998.
- Monitoring and Target Setting – Implementation Manual, Energy Efficiency Office of Department of Energy, U.K., 1991.
- Energy Efficiency Opportunities – A series of guidebooks, published by industry associations and funded by the Office of Energy Efficiency, Natural Resources Canada:
    - The Solid Wood Industries; The Council of Wood Industries, 1997
    - The Canadian Rubber Industry; Tire Technologies Inc., The Rubber Association of Canada, 1997
    - The Canadian Brewing Industry; Lom & Associates Inc, The Brewers Association of Canada, 1998
    - The Dairy Processing Industry; Wardrop Engineering Inc, The Dairy Council of Canada, 1997
    - In the Kraft Pulp Industry; Agra Simons Ltd., The Pulp and Paper Technical Association of Canada, 1998
- *Compressed Air Costs Reduced by Automatic Control System*; U.K., 1995.

- *Ultrasonic Detection of Compressed Air Leaks*; Australia, 1999.
- *Heat Recovery From an Air Compressor*; New Zealand, 1995.
- *Variable Speed Drive for an Air Compressor Reduces Electricity Consumption*; Denmark, 1998.
- *Expanding an Existing Compressed Air Grid With a Low Pressure Section*; The Netherlands, 1997.
- *Control Optimization*; U.K., 1994.
- *Cascaded Use of Waste Heat From Gas Turbine Cogeneration by Steam Expander*; Japan, 1999.
- *Energy Recovery Unit for Wide Range of Industries*; New Zealand, 1997.
- *Supersavers: A Workforce-led Initiative to Save Energy and Reduce Waste*; U.K., 2000.
- *Energy Monitoring System*; Canada, 1999.
- Expert System Improves Performance of Plant Controlled by Programmable Logic Controllers; U.K., 1994.
- Adjustable Speed Drives Improve Ventilation at a Metal Plating Facility; U.S.A., 1996.
- *Demand Side Management (DSM) Technology Benefits Steel Producer*; Canada, 1992.
- *Compressed Air System Combined With Cogeneration in Factory*; Japan, 1994.
- *How to Succeed – Your Process Integration, Water, Effluent and Energy Study*; S. Gennaoui, Proceedings of the Canada's Energy Efficiency Conference 2000.
- Reports and fact sheets published by the Canada Centre for Mineral & Energy Technology (CANMET):
  - High Energy-efficient AC Motors (FS10)
  - Adaptive VAR Compensator (FS12)
- Newsletters by the international Centre for Analysis and Dissemination of Demonstrated Energy Technologies (CADDET):
  - *Compressed Air: Savings of 30 Percent Are Quite Normal*; The Netherlands, 1999.
  - *Compressed Air Challenge™ Communicates Better Management*; U.S.A., 1999.
  - *Upgrading Industrial Waste Heat Using a Hybrid Heat Pump*; Norway, 2000.
  - *Electricity Consumption of Compressed Air Reduced by 60 Percent*; Denmark, 1999.
  - *Compressed Air System from "Demand Back Through Supply"*; Belgium, 1998.
  - *Presentation to the Canadian Soft Drinks Association*; V.G. Munroe, Office of Energy Efficiency, Natural Resources Canada, 1997.

- *CAN/CSA-850-10 Standard: Risk Analysis Requirements and Guidelines*; 2010.
- *Do your Product Development Math*; Reinertsen & Associates, Machine Design, May 1998.

The use of the above-listed sources is also recommended to any reader wishing to obtain further information.