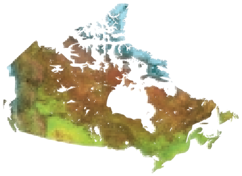
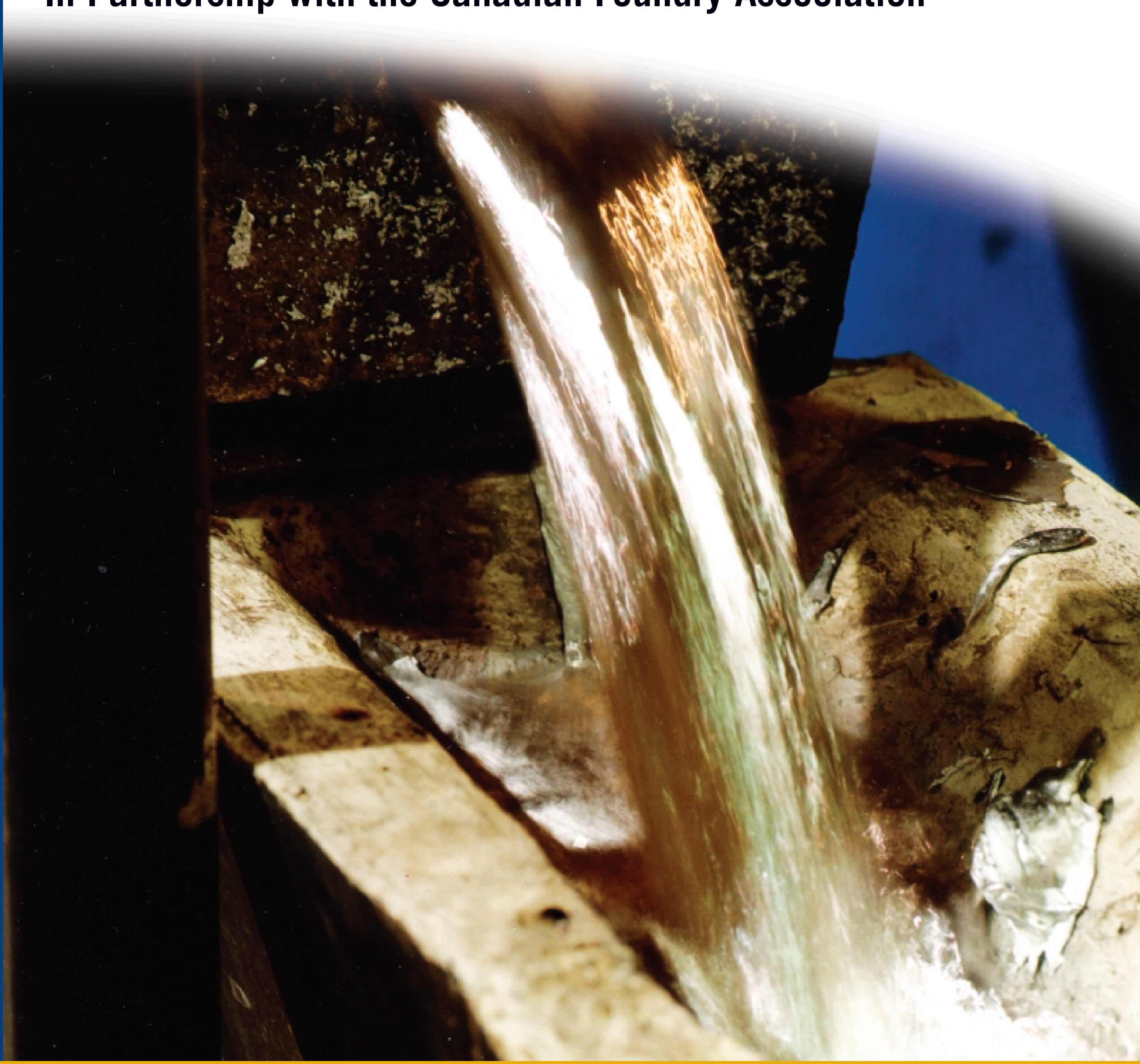


Canadian Industry Program for Energy Conservation
CIPEC

Guide to Energy Efficiency Opportunities in Canadian Foundries

In Partnership with the Canadian Foundry Association



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Canada

Energy Efficiency Opportunities in Canadian Foundries

Energy Efficiency Opportunities in Canadian Foundries is a joint project of the Canadian Foundry Association and Natural Resources Canada through the Canadian Industry Program for Energy Conservation (CIPEC).

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Introduction

For the average foundry worker, the area of energy consumption is a confusing and little studied area. The aim of this book is to give the foundry professional a practical, concise and systematic guide to improving energy efficiency in a foundry. This guide covers the following key elements:

- Performing energy audits and determining the gaps;
- Gathering energy conservation ideas;
- Selecting and prioritizing projects; and
- Charting the course of improved energy performance.

"Foundries need to understand not only how they use energy, but also how energy consumption patterns affect costs." – L.V. WHITING

This guide came into being thanks to the joint initiative of the Canadian Foundry Association (CFA) and the Office of Energy Efficiency (OEE) of Natural Resources Canada (NRCan), under the auspices of the Canadian Industry Program for Energy Conservation (CIPEC).

> The CFA has a mandate to work on behalf of its members to create a climate for consistent and sound economic performance.

The CFA was incorporated in 1975 by a group of owners and CEOs at Canada's leading foundries who realized that there was a need for a united representation of the industry's interests. Today, the CFA comprises major metal casters operating over 50 plants throughout Canada and representing over $2 billion (or 80%) of production and sales in the Canadian foundry industry. The industry directly employs approximately 15 000 people, with about 10 000 of them in Ontario.

The CFA provides one voice to address specific issues that affect the industry and to represent members in relations with the Government of Canada. Within a decade after its formation, the Canadian foundry industry faced a serious trade dispute with the United States. Foundries on both sides of the border were hit hard by the recession of the early 1980s. American foundries attempted to restrict imports of castings into the U.S., a move that would have been devastating to the Canadian foundry industry, since most of its exports go south. Following a major lobbying effort, the CFA was successful in blocking the attempt to restrict Canadian casting exports. Recently, environmental concerns and the effective usage of energy in foundries have gained considerable prominence.

The CFA participates in the Canadian Industry Program for Energy Conservation (CIPEC) and states its commitment to reduce greenhouse gases in support of the Government of Canada's objectives and international undertakings. Energy efficiency is recognized as a means of reducing investment in energy supply to save Canadian foundries money and to improve their competitiveness in domestic and global markets.

In the fall of 2000, the CFA, in concert with the OEE of NRCan, commissioned the establishment of an energy baseline for the foundry industry (leading into benchmarking later), as well as the production of this guidebook. The guidebook will give Canadian foundries a practical tool to use in acting on the many energy efficiency opportunities in their operations – perhaps overlooked or unrecognized until now.

How to use this guidebook

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

Read all of the guide first, no matter what type of foundry operation you have and what your energy-related priority is right now. You are apt to find ideas that you can easily adapt to your own particular situation. Most likely, those ideas may offer a synergistic solution to a particular problem. While you are reading this guide, free up your imagination and the spirit of innovation about which ideas you could apply in your plant.

Modern energy management involves many interrelated energy-consuming systems. Get the overall view by reading the entire guide first.

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

This guide contains updated references to proven, innovative energy-saving practices from many countries. They relate to specific foundry processes as well as to common energy-using systems, such as compressed air and ventilation. The distinctiveness of different foundry operations presented a special challenge in writing this book. Every attempt has been made to address common interests. Various sources of valuable current information from all over the world were used, including personal communications from Canadian foundries and the Canadian Centre for Mineral and Energy Technology (CANMET) of NRCan. They are referenced in the Information review section (in Appendix 5.8).

Acknowledgements and disclaimer

The Canadian Foundry Association gratefully acknowledges the OEE of NRCan for providing the required funding to develop an energy management guidebook.

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The authors express their sincere appreciation to Judy Arbour, Executive Director of the CFA, for excellent project leadership and effective organizational support. In addition, thanks are due to Brenda Budarick of the CFA for able administrative assistance.

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Thomas Warren	– Gamma Foundries Limited
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The generic opportunities as presented by the authors of this guide, commissioned by the CFA, do not represent specific recommendations by either party for implementation at individual foundry locations. The authors and the CFA are not responsible for any implementation without prior consultation and further detailed site evaluation. The use of corporate and/or trade names is not meant to constitute an endorsement of any company, commercial product, system or person.

Profile of the Canadian foundry industry

Metal castings are the first step in the value-added manufacturing chain and are utilized in the production of most durable goods. Foundry operations have always been varied and complex, and they have become even more so. The industry has changed fundamentally in the last five to 10 years. Foundries no longer produce only raw castings. Today, many modern foundries design the parts, build the tooling, cast the prototypes, make the castings, machine them, assemble the castings, and produce a component or assembly ready to install on the customer's assembly line. Therefore, the foundry sector is no longer only foundry operations. Many foundries are designers, casters, machiners and assemblers of value-added parts.

"No industrial society has been successful without a vibrant foundry industry base."
– Michael Promoli

There are currently about 200 foundries in Canada. The CFA's membership comprises large, medium and small foundries. Some are custom producers while others are captive operations. Makers and industries served by foundries include the automotive sector, construction, agriculture, forestry, mining, pulp and paper, heavy industrial machinery and equipment, aircraft and aerospace, plumbing, soil pipe, municipal road castings, defence, railway, petroleum and petrochemical, electric distribution and a myriad of specialty markets.

In foundries, raw material is mostly recycled metal. Virgin metal accounts for only very small additions to specialty formulations and is also used in some aluminum and brass foundries. A wide range of technologies and equipment is being employed, depending on the type of metal worked, the business situation and the plant condition of different companies. Their common denominator is high energy usage per unit of product as well as high percentage of total operating costs.

By using recycled scrap metal, the metal-casting industry contributes quite significantly to the conservation of natural resources and energy. Nevertheless, Canadian foundries are prodigious users of energy – it is estimated that they consume some 6300 TJ (or 1.75 billion kWh) of energy annually. Depending on the type of metal alloy cast, the casting technology used and the age of the plant, the energy utilization and its portion of the total operating cost may vary greatly. This is illustrated by the table "Energy benchmarks in foundries" in Appendix 5.2, which is well worth a look.

Please note: Commonly, the 2000-lb. ton (short) is used as a unit of measure in foundries. For reasons of standardization and to facilitate international and between- industry comparisons, **the international SI (metric) system will be used throughout this guide** (one metric tonne [t] = 2204.6226 lb. = 1.10233113 ton [short]).

Currently, there appears to be a lack of reliable information on the total production and benchmarking data of Canadian foundries; no single organization is known to keep track of all of it. The CFA is currently addressing this problem and exploring whether its annual industry survey, which collects foundry-specific data, could be included in Statistics Canada's program.[1] Needed data can be produced based on Standard Industry Classification (SIC/NACE) codes. NRCan's OEE also has relevant energy-related data that could be accessed. The CFA plans to continue to collect tonnage data.

Composition of the foundry industry

Predictably, as with most of the industrial production in Canada, two thirds of all foundry output is produced in Ontario. Most of the iron foundries in Canada supplying the automotive industry are located there. The most prevalent metal cast in foundries is grey iron. Appendix 5.5 lists the CFA's member foundries by metal type cast.

> In practical terms, to produce a tonne of good brass castings, two tonnes have to be melted, cast and worked on!

Trends in energy use

Over the last decade, there has been a marked shift toward electricity and natural gas in the type of energy that foundries use. While aluminum casters increased the use of natural gas for melting, iron producers introduced more electric induction furnaces. Around 1980 there were 40 coke-using cupolas producing close to 1 million tonnes of iron (or 75% of total). The melting capacity of these furnaces is many times greater than that of the largest electric induction furnaces. The efficiency feature notwithstanding, the environmental and regulatory pressures and expensive anti-pollution equipment, which the operations of cupolas now require, caused their number to dwindle to about 12 units, accountable for an estimated 360 000 t today.

The rapid escalation of natural gas prices in 2000 and the deregulation of the electricity market have spotlighted the need to address energy efficiency issues. In grey iron production, melting accounts for 66% of the energy consumption; in steel foundries it is 50%; and in brass and bronze foundries, the figure is 38%. As can be seen from Appendix 5.2, on average, the total energy content in 1 t of good (shippable) iron castings is 50% higher, in steel castings 60% higher, and in brass and bronze castings 100% higher than the energy required to melt 1 t of the metals. All kinds of inefficiencies contribute to this fact.

[1] Because tracking of energy use in the foundry industry in Canada is not systematic, some of the tables and figures used in this guidebook are included only to show trends.

Environmental considerations

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

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

The CFA monitors environmental issues. As well, a major lobbying effort was made to have spent foundry sand classified as engineered and inert fill in landfill sites. It can now be used as daily cover.

As an industry sector participant in CIPEC, the CFA is working to help Canada meet its international climate change commitments.

Two recent independent studies concluded that the Canadian foundry industry is generating less than 1% of Canada's total carbon dioxide emissions – a chief contributor to global warming. One should not dismiss the low figure; it represents a huge amount – about 6 million t – of the carbon dioxide gas being emitted every year.

Improved energy efficiency reduces greenhouse gas emissions in two ways:

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

For an example of how to calculate the amount of reduction in major greenhouse gas emissions resulting from your energy efficiency projects, look up Appendix 5.4, "Calculating reductions in greenhouse gas emissions."

Foundries must also pay attention to the composition of their air emissions. The newly released (March 2001) air quality standards in Ontario set tougher limits to be met. Projects designed to meet emissions standards can be capital intensive. A project, spawned by a regulatory requirement, can be easier to justify by combining it with an energy management project that reduces energy usage.

1.0
Setting up an Energy Management Program

1.1 How to get started

People the world over are feeling increasingly concerned about the health of the environment in which they live – witness the efforts to stem the global warming effects of greenhouse gases. To start with, an energy management program offers a unique opportunity to marry the goodwill most people feel toward doing something positive for the environment with achieving a business objective of reducing energy consumption. These two objectives go hand in hand.

"We want to save energy because we know it helps achieve a higher order objective – the environment in which we live. ***We do it because it is the right thing to do!"***
– A MOTIVATED EMPLOYEE

The primary driver in the most successful energy management programs is the feeling of collective responsibility for the environment, and the effort to help it. This should be the rallying point for the foundry's troops when starting the program!

"Taking care of the environment makes good business sense."
– JACK WELCH, former CEO, GE

Innovation and **efficiency** improvements are the key words in the struggle for survival and prosperity in the globally competitive foundry business. Business managers often underestimate the potential savings that can be realized by reducing energy consumption. Until recently, in most industries energy costs were regarded simply as a cost of doing business, and little attention was paid to them. The level of interest in efficient energy use had been moderated by continuing low oil and natural gas prices that prevailed until 2000. Also typically, a foundry would have little knowledge of energy issues within the plant and other utilities it had bought.

"The business of business is to stay in business." – PETER DRUCKER

The steep escalation of energy prices in 2000, together with concerns about market competitiveness, control of greenhouse gas emissions and energy supply security, added urgency to the need to examine the effectiveness of energy use in foundries.

It is in any company's strategic interest over the long term to control the consumption of energy, hence its cost.

This has not been lost on any company's president, of course. However, the realization of the need for improved energy efficiency must progress beyond a mere acknowledgement, a "motherhood" statement – it needs to result in an action. Nothing commands attention more than the dollar sign – and the plant accountant can prove to be a valuable ally in the energy battle plan. Table 1 provides an illustration of how this works.

TABLE 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

Tip

An energy audit can be used to improve a foundry's competitiveness.

On the background of basic cost information, a case can be made for an effort to start to determine the current state of energy consumption, and then to do something about it. Compiling additional information on the current consumption patterns will involve a *key step – an energy audit* (see below). The resulting reasoned and justified argument will give the energy issues a chance to stand out among a number of other priorities competing for the attention of top management.

The assumption of 35% energy savings in Table 1 is not far-fetched. It should be remembered that worldwide experience has shown that mere improvement in ordinary housekeeping practices (i.e., minding the energy connotation of every-day work, such as switching off unneeded equipment, etc.) typically produces 10–15% savings! Additional energy savings can also be obtained as conservatively shown on Table 2. The table is a compilation of results from many energy audits of Canadian foundries undertaken in the few past years by CANMET. It shows the magnitude of energy savings identified by an energy audit that can be realized in an average foundry.

TABLE 2:

Summary of expected results based on end use consumption

Equipment / process	Consumption of total plant energy, %	Area savings potential, %	Overall plant savings, %
Melting	59	15	9
Fans and pumps	6	35	2
Lighting	6	30	2
Motors	12	10	1
Air compressors	5	20	1
Miscellaneous	12	10	1
Total	97*	–	16

Table by L.V. Whiting

*Variation due to unaccounted influences

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

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

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

These points are further expanded upon in Figure 1 and in Section 3.4, “Developing energy management programs further” (page 99).

Energy management is an ongoing concern in any foundry. Its success depends on a team effort starting with a firm commitment from the top executive and his or her management team. Management’s demonstration of unwavering, solid and visible support filters through the organization to each employee. Everybody will take heed and will follow the example.

Once the decision to manage energy has been reached, it should be supported by a board-level energy policy, which will regard energy and the cost of utilities as direct costs on par with other operational costs, such as labour, raw materials, etc.

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

A buildup of general awareness about energy issues through communication, education and training of employees at all relevant levels will contribute to a cultural change within the organization. Education and training must be sustained in order to achieve lasting energy efficiency improvements.

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

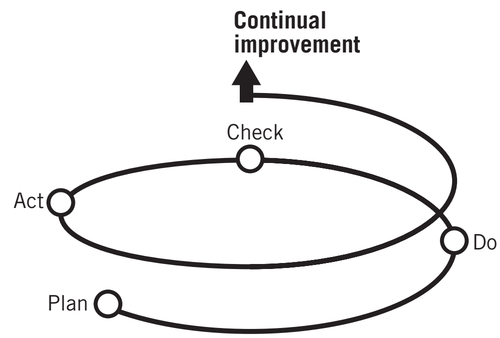
- Was not aware of opportunities that exist;
- Did not know what to do;
- Top management not supportive;
- Energy issues not a priority;
- No money and/or staff and/or time; and
- No defined accountability.

Tip

A dollar saved goes directly to the bottom line!

Since the primary business goal is financial savings, managers must understand the principle of economics and run their department as if it were their own business. In doing so, improving energy efficiency should get proper attention. This will require some education. Even if the financial gains from energy efficiency improvements were to seem modest compared to the value of sales or to the overall budget, they can contribute considerably to the foundry's net profit.

An energy management program follows the same principles that apply to any purposeful undertaking (e.g., to quality and environmental management systems) – principles that Dr. Deming formulated as the four-step cycle, **P**lan – **D**o – **C**heck – **A**ct, PDCA, shown below.



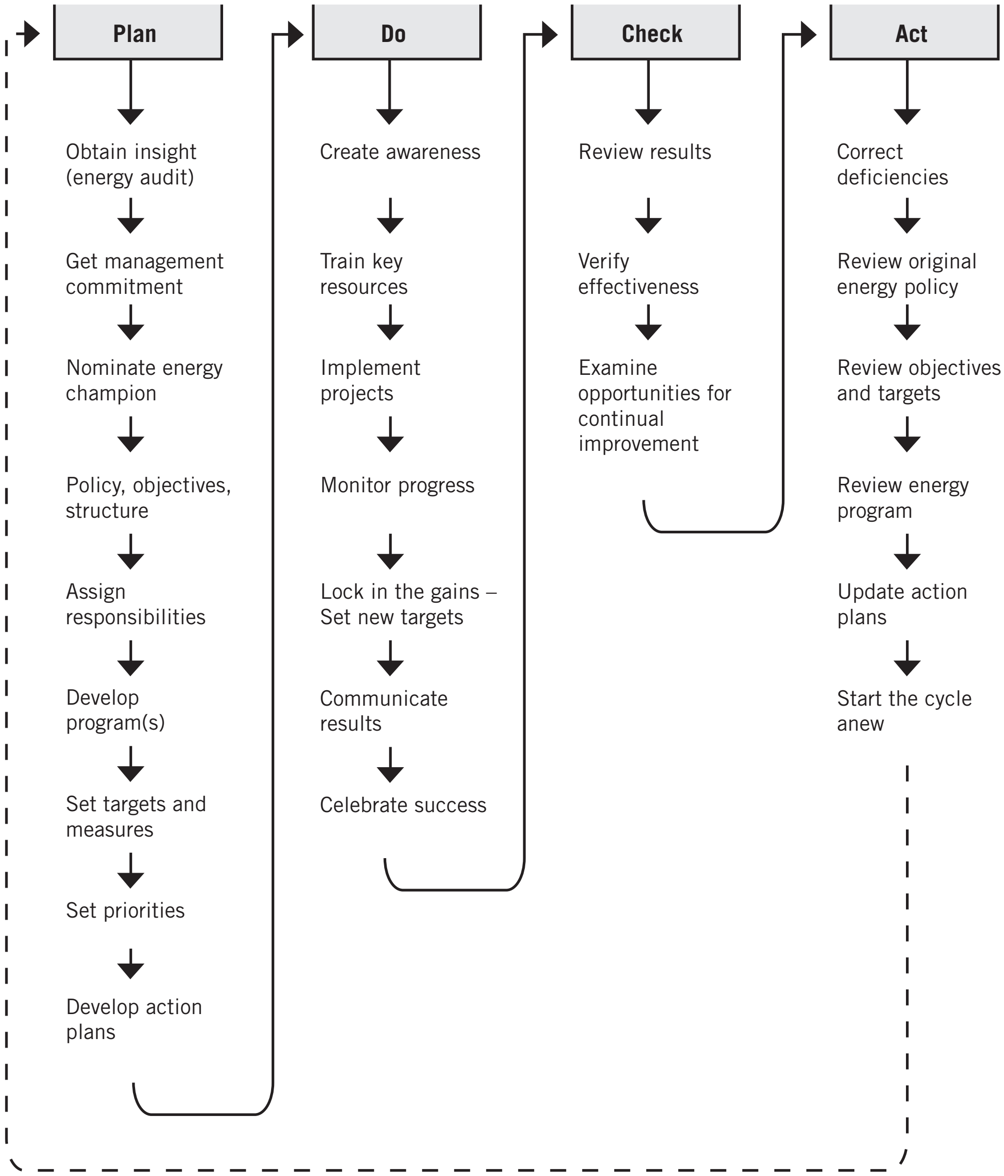
The details of these four key steps are shown in Figure 1.

To realize opportunities, foundry management must successfully integrate organizational and behavioural (cultural) change and new energy use technology.

The energy efficiency effort must have a defined focus, accountability and responsibility.

The points in Figure 1 are generic and given for information only. Their application will vary with the size and complexity of a foundry's operations and will be determined by site-specific conditions of a particular energy efficiency improvement program.

FIGURE 1:
Energy management plan at a glance



1.2 Auditing energy use in a foundry

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

Following is a list of practice-proven steps in energy auditing.

Energy audit purpose

Why have an audit[2]? Can't an excellent energy conservation project yielding good financial return be undertaken without an audit?

Yes, it can. It is likely, however, that without the systematic approach of the audit, this ad hoc application of energy management may cause many opportunities – some of which could be better than expected – to be missed; thus the benefits of projects' synergies would remain hidden.

An audit has four main stages:

1. Initiating the audit;
2. Preparing the audit;
3. Auditing; and
4. Reporting the audit results.

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

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

1.2.1 *Initiating the audit*

Define the objective(s)

It is the role of top management to define the scope and objective(s) of the energy audit. What is to be achieved? The determination of an 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?

Define the audit scope

The scope of the audit is established by the foundry's management. 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 foundry or a particular operation, e.g., melting.

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

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

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

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

Selecting auditors

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

The selection of an auditor (auditors), then, is all-important. Choose people who are available and have the skills required for what is needed. The person should be objective, of high personal integrity and sound judgement – 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 obtain much of the information in personal interviews and discussions with the foundry operators and staff. To gain the necessary cooperation, the auditor's ability to establish a good rapport with employees is essential.

> The audit process and its results must be credible.

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

- On the surface, the cost of foundry staff's help will be considerably less costly than what a consultant would charge. It is possible that the audit would interfere with some of the routine work of the foundry's staff, who would participate in the audit.
- A learning curve will inevitably be involved. Errors may be committed. For foundry staff, the overall time requirement would be significantly more, possibly twice as much as a consultant would require. Staff may also be biased. They may have become oblivious to certain aspects of their operations. They may not have the broader experience, which facilitates knowledge transfer from other or similar situations, and which a consultant would probably have.

Budget and audit duration estimation

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

1.2.2 Preparing the audit

Plan and conduct the energy audit with the intent to determine energy inefficiencies in the foundry process as well as energy losses in the "waste" streams.

Timing of the audit

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

A period of one to three weeks, when the foundry 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 foundry 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.

Let us suppose that you will be able to collect data over the highest production period. It is likely that the foundry will not operate at this rate all year long but at some average level below that. 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.

Determine the production baseline

Among other things, you will want to use the audit results to establish energy consumption levels based on average production. Normally, foundries do not have this information available. Such information would, however, facilitate future energy management, including setting energy consumption targets, quantifying eventual energy savings, budgeting, planning capital expenditures and helping to set true current costs per production unit, to cite a few examples.

Gathering available information

Historical statistics, such as cost of fuels and electricity (annually and monthly), purchase of raw materials, supplies (sand, binders, shot, refractories, etc.), waste disposal data (volumes, tonnage, costs and revenue), production data (good castings, scrap, rework, material losses) and labour data should be relatively easy to get in most foundry operations. The material inventories should be established before and at the close of the audit. You will need this information when verifying or calculating the material and energy balances.

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

Getting the tools

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

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

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

Electric power consumed by major equipment needs to be measured. A foundry may consider it useful to purchase an energy analyser for its ongoing energy program (complemented by a phase analyser, which is necessary in order to properly see the sine wave). This would require an investment of about $4,500. The analysers can also be rented or borrowed from an electrical utility. A consultant may have his or her own set.

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

1.2.3 Auditing

Gathering information

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

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 cross-check and reconcile energy data as one of the means to verify the accuracy of the audit observations and support its conclusions. They are useful for evaluation of the impact of foundry development plans and certain types of energy-saving projects.

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

Balances include the following:

- Power balance
- Natural gas (and/or oil) balance
- Steam and condensate balance
- Water balance
- Material balance (raw material to good castings)
- Sand balance, etc.

The balances can be undertaken for the entire foundry or can be limited to key equipment affected (e.g., the melting furnace, 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 in the appropriate streams on the flow diagram.

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

Practical production considerations

In the course of auditing gas-fired and oil-fired furnaces, the auditors may often find that there is a lack of controls for these furnace types. In uncontrolled burning, the fuel-air mixture is not optimized, so fuel is wasted whether the mixture is too rich or too lean. In the former case, furnace temperatures are frequently excessive. In addition, there may be metallurgical problems associated with uncontrolled burning, such as excessive hydrogen content in molten aluminum.

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

To account for energy losses, the auditor should also pay attention to the process equipment and how it is used. For example, assess melting and holding furnaces and their lids; the state of their repair; how the ladles are preheated; how the molten metal is conveyed, handled and poured; what the temperature gradients are at each stage; etc.

As well, an energy audit should consider examining casting yield and scrap rate (see the ratio between good castings and metal melted in Appendix 5.2) and how the scrap is utilized. Clearly, casting yield greatly influences materials and energy consumption (and primarily, of course, the foundry's profit).

1.2.4 *Reporting the audit results*

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

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

The audit report will typically contain:

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

1.3 Understanding the audit results

With the delivery of the audit report, the process of key importance – an energy audit – has been concluded. The diligent and professional work of the energy auditors has produced a report with results reflecting that particular slice of time when the audit was conducted. Although not absolute, the results can be extrapolated with reasonable accuracy to the foundry's average 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 offer very concrete directions regarding energy management. For example, an aluminum foundry may wish to consider switching fuel sources for melting, particularly if a mass balance was also undertaken. Melting losses for aluminum, typically 7% with older gas-fired furnaces, can be reduced to 0.5% with electrical melting. Electricity is a more expensive energy source. Nevertheless, when the annual cost of lost aluminum (at, say, $1.60/kg) as well as the positive impact from improved quality of castings (i.e., lower reject/scrap losses, reduced rework) are considered, the payback from switching to electricity may be found to be very attractive.

There will be two likely energy audit outcomes:

- Establishment of a foundry-wide energy management program; and
- Prioritization of an energy efficiency improvement project, indicated by the audit, for the energy management program to address.

1.4 Implementing the energy management program

The generic plan of an energy management system (see Figure 1 on page 11) represents an ideal, proven scenario, where the various steps are approached in a rational, reasoned and systematic manner. Try to adopt as many of these steps as you can in your specific circumstances. If you create an energy management system successfully, you will be able to launch successful energy management programs as well.

Top management commitment

The close involvement of middle and top management and its ongoing, visible commitment will greatly improve the effectiveness of the energy management system. Once the results of an energy audit are in, the energy management program should have a designated individual who is accountable for its implementation.

Nominate the energy champion

The energy champion should be a technically competent person who has the respect and support of the foundry staff and employees. The champion should be a "doer" – and a good organizer, facilitator and communicator. The champion should demonstrate high levels of enthusiasm and deep conviction about the benefits of the energy efficiency program and be an eloquent advocate of the cause. For the energy champion to have free access to senior management, the position should be an executive-level appointment. The size of the foundry will determine whether it should be a part-time or full-time position.

> NRCan has published an excellent resource, "Tool Kit for Your Industrial Energy Efficiency Awareness Program." E-mail NRCan at indust.innov@nrcan.gc.ca for a free copy.

Set energy policy and create awareness

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

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

Decide on objectives

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

Assign responsibilities

The champion chairs the Energy Management Committee (EMC) and takes overall personal responsibility for the implementation and success of the program and accountability for its effectiveness. The EMC should include representatives from each major energy-using department – from melting to finishing and maintenance, and from production operators. In smaller foundries, all management staff should have energy consumption reduction duties.

Allocate resources

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

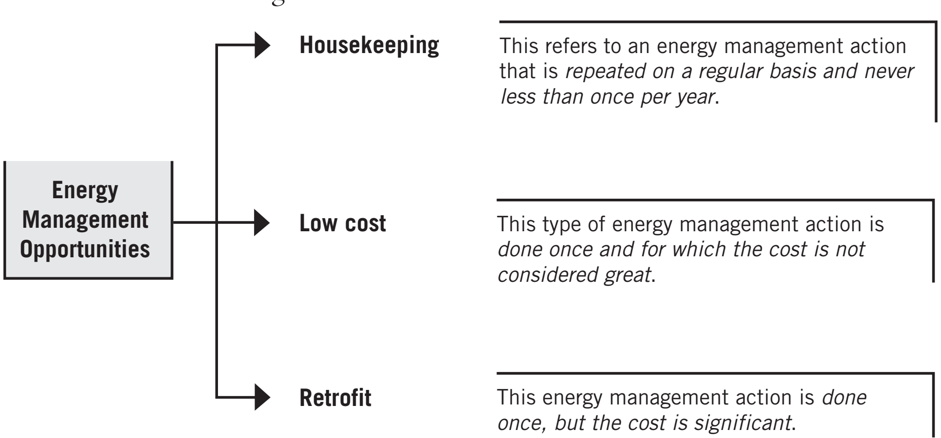
Develop program(s) for energy efficiency management
Develop targets and measures
Set priorities

See Section 3.0, "Putting it all together: Closing the gaps" (page 89), where these subjects are treated in context.

Develop action plans

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



We shall use this classification in describing the EMOs later on.

Train key resources

With an advantage, training can be organized in two stages. The first is specific training for selected employees, i.e., those who will be involved in energy management program and have a greater influence upon energy consumption than others. The second – following in due course – is a strategy for integrating energy management training into the existing company training matrix, to ensure that energy training is regularly covered. Generic team training, e.g., in conflict management and problem solving, should also be provided to the EMC members.

NRCan sponsors a number of specific energy efficiency improvement courses, in collaboration with local colleges and through the Canadian Institute for Energy Training (CIET) across Canada. Other sources of training are available through utility companies and other organizations; see Chapter 4, "Sources of Assistance."

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 perhaps only modest but quickly obtainable savings, especially projects to correct the obvious sources of waste found in the initial energy audit. The early successes will encourage the team to tackle bigger projects and seek greater savings. With growing confidence, they will address areas of less obvious energy consumption, such as energy used in heating and ventilation of the foundry.

Tip

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

Monitor progress
Lock in the gains – set new targets
Communicate the results

Please see Section 3.0, "Putting it all together: Closing the Gaps (page 89), where these subjects are treated in detail.

Celebrate the success

This is often an overlooked yet very important part of a program. People crave and value recognition. Myriad ways can be employed to recognize the achievement and highlight the contribution of teams (rather than of individuals – which can be divisive!): giveaways of thematic T-shirts, hats and other merchandise, dinners, picnics, company-sponsored attendance at sporting events, cruises – there is no end to it. The achievement of a target should be celebrated as a milestone on the way to continual improvement of energy efficiency in the foundry.

> Celebration of success is a motivational tool that also brings psychological closure to a project.

Review results

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

Verify effectiveness

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 verified so that adjustments can be made and future projects better managed.

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

Examine opportunities for further improvements

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

Correct deficiencies

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

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

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

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

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

1.5 Involving employees

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

The initial step is to increase energy awareness. Focus first on elimination of wasteful practices, i.e., better housekeeping.

- Form a team of volunteers from different departments, and give it a catchy slogan (e.g., The Super Savers, Energy Cost Slashers, Energizers, Fight Energy Costs!, etc.). Launch it with hoopla!
- Mount a publicity campaign: use existing means of communication to stimulate interest. (Mail special news bulletins directly to employees' homes, use posters, information sheets and energy efficiency handbooks for all employees. Plenty of these can be obtained from different sources.)
- Explain simple, good housekeeping methods. Concentrate on one type of energy at a time, for example, natural gas, electricity and compressed air.
- Give pats on the back: encourage, monitor progress and report improvements.
- Stick to it, to make the change permanent.

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

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

Before the project, only 10% of the work force regularly took practical energy-saving actions. The percentage increased to 85% after the project. Suggestion programs may help, as well. They need to be maintained systematically and constantly, however, to yield results on an ongoing basis. Some maintain that it is better to base these programs not on the initiative of individuals, but rather on a team approach. This minimizes the potential of divisive personal rivalries. Another solution is to approach the issue of energy efficiency in a foundry as an opportunity for continual improvement, and use any of the number of proven techniques to achieve it: Quality Circles, Kaizen, Total Quality Management (TQM), etc. Of course, if the environmental management system ISO 14001 is implemented, the continual improvement is embedded in this international 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 2.1.11, "Implementing a management system," page 35).

Ongoing training also helps. A foundry in Eastern Ontario invests two hours of training per employee per week as matter of policy. Part of the training also deals with energy efficiency matters.

2.0

Getting Ideas for Energy Management Opportunities

2.1 General foundry management

2.1.1 Building design and plant layout

Energy Management Opportunities (EMOs) is a term that represents the ways in which we can use energy wisely to save money.

The opportunity to design a foundry and prepare an effective layout of the process and equipment is rare. It is a complex subject, well beyond the scope of this guidebook. In trying to find an ideal solution, many often-conflicting requirements would have to be reconciled. For example, a new, "green" field-built foundry should:

- Utilize the space available in the building maximally;
- Facilitate a natural process flow, with easy access for in-plant transportation, operators and maintenance;
- Provide a healthy and environmentally sound workplace;
- Allow for future expansion of the plant so that it could merge organically with the existing operations;
- Minimize distances for transporting materials (e.g., scrap, returns, sand, moulds) and conveying molten metals;
- Allow for dry and ambient-temperature storage of raw materials, particularly scrap;
- Include a provision for utilization of all major opportunities for energy conservation, described elsewhere in this guidebook; and
- Have effective dust removal and ventilation systems, which use locally available sources of waste heat for winter heating.

From the energy point of view, the biggest planning problem is to supply the furnaces with scrap and returns and to get the molten metal to pouring as effectively as possible. Poor planning of these two essential transport systems can effectively *double energy costs*!

Proper planning of localized exhausts from dust and/or emissions-producing pieces of equipment can be done after the design stage of the production layout rather than before. Otherwise, the result could be over-dimensioned foundry ventilation, which wastes energy in excessive air change and heating the make-up air.

A new foundry facility should reach for a higher level of performance than what is current, in every respect. The requirement to improve energy efficiency should be built into the design and quantified. The quantification provides a useful cross-check. The existing foundry can provide the specific energy consumption, **X**, in MJ/kg of product (unit of product), against which the projected specific energy consumption, **Y**, is compared. The projected value would be a close estimate at this point, given the project's various development issues, and would be based on manufacturers' data for certain key pieces of equipment. The **Y** value should include consideration of all the energy imported into the operations, from which energy recuperated by the project's new energy-conserving features (such as hot water for general building heating, steam for a cogenerator) has been subtracted. The new foundry's energy efficiency is then expressed as

$$\mathbf{E\ (\%) = [(X - Y)\ /\ X] \times 100.}$$

This approach, practised by some well-known, major industrial companies, ensures that energy-saving features are built into each new capital project, whether it is buildings, a casting line or individual capital equipment purchases.

Each new project involves making compromises between what is desirable and what is possible within the project restraints, such as budget, space, etc. The energy efficiency of a project is one of the criteria that may be subjected to these considerations. An explanation of a simple technique to use in judging the effects of project trade-offs is described in Section 3.3, "Selecting and prioritizing EMO projects" (page 92).

2.1.2 Transportation and distribution factors

In deciding where to locate a new plant, transportation issues also play a role among myriad other considerations, such as land availability, absence of previous land contamination, local business environment, availability and cost of utilities, etc. Cost of transportation and its portion of overhead costs are becoming increasingly important. When looking at the transportation issue, it is desirable to take a broader view of emissions and what can be done to minimize the foundry's impact on the generation of greenhouse gases in operating transportation equipment. From the transportation viewpoint, some of the following points may be contemplated for a new plant:

- Proximity to major (potential) customers (particularly if deliveries would be made in just-in-time environments);
- Proximity to major competitors (potential availability of skilled labour);
- Easy road transportation access;
- Easy rail access (potential for rail spur on site); and
- Potential for a two-way utilization of cargo capacity (raw materials in, product out).

For existing foundries, the transportation question boils down to making sure that the costs of transportation, in $/km travelled, and of the upkeep of the fleet (if foundry-owned, similarly expressed) are minimized. As to the former, a foundry should ensure that unnecessary trips are eliminated. This can be achieved by combining deliveries, optimizing travel routes, and ensuring that a payload can also be secured for the return portion of the trip. It also pays to investigate joint delivery/supplying opportunities with other businesses in the neighbourhood, and to talk to your transportation broker. This also includes discussions of freight rates and available services with the local rail company.

Regular preventive maintenance of the foundry trucks should be conducted in order to reduce the incidence of breakdown, lengthen useful truck life and minimize operating expenses (such as fuel consumption).

Other EMOs

Housekeeping

- Maintain all vehicles, including lift-trucks, in top operating condition.
- Do not let the engines idle; turn them off while waiting, and during unloading, breaks, etc.
- Use the proper size of truck for the job.
- Combine deliveries with pickups or sales calls wherever possible.
- Optimize transportation and sales call routes.

2.1.3 Design influences

Ideally, the design process should lead to optimized mould design, allowing production of good quality casting, fit for use, in the shortest time possible, with a high yield ratio and at the lowest cost. Some of the features of good design, which can improve yield, are described below. Design includes more than the casting. It must consider also the technology employed in making the casting. In such cases, experiences and good practices described in other chapters may be applied.

The traditional reliance on foundry experience and a trial-and-error approach makes development of new casting designs expensive and slow. Trying to solve unexpected casting faults is a hit-and-miss affair and takes time and effort. The majority of casting defects are caused by the use of inadequately or incorrectly placed feeders and runners. **Rapid prototyping** technology uses computer simulation and X-ray videography to optimize their placement.

Computer simulation

The use of computer simulation (e.g., by such powerful software programs as Magmasoft®, Finite Element Solidification Analysis EKK®, CastView®, Pro/Engineer®, Flow-3D®, Unigraphics®, SolidEdge®) substantially speeds up casting design development and has a number of other benefits:

- Produces a three-dimensional, solid geometry model of the casting, which includes the proposed arrangements of feeders and runners;
- Predicts the cooling sequence of various sections and of the entire casting. It can make the solidification visual, and images can be combined in sequence to produce a casting/cooling video;
- Any number of alterations to the design is possible, and a permanent record is made of each stage and the resultant predictions;
- Helps to cut down on the use of metal (increasing the casting yield) by careful positioning of feeders and the use of exothermic insulators and chills;
- Predicts where shrinkage is likely to occur;
- Allows optimization of adjustments to feeders and runners, before making a casting; and
- Helps with troubleshooting, by modeling, to identify the cause of unexpected casting faults.

> Computer simulation reduces lead times in supplying sample castings, reduces mould-making and modification costs, reduces scrap due to shrinkage porosity and, by reducing customer rejects, improves customer confidence.

All of the above result directly in energy efficiency improvements. The start-up cost for a computer simulation set-up, including the software and training, may run well over $100,000, with substantial yearly maintenance charges. However, in a documented case of two offshore foundries, the yield improvement rate was over 20%, and paybacks ranged from three to eight months.

X-ray videography

This technology helps to validate the computer simulation and takes a scientific approach to mould design. It allows viewing of molten metal flow through mould cavities and helps to achieve optimized mould design.

Filters

When designing moulds (or dies) for non-ferrous castings, consider incorporating ceramic filters for the molten metal in order to realize numerous benefits (see Section 2.3.6, "Pouring," page 66).

Lighten risers

Consider emulating the steel foundries practice of insulating risers as a way to reduce their weight. Reduction of weight to one sixth or less of the original may be possible.

Lighten castings

Investigate whether removing metal from the casting designed by the customer would be possible without impairing the required functional properties (such as strength and durability). Apart from the practical cost/profit considerations (more pieces produced per tonne of metal), the process would save energy normally required.

Robotic casting

A designing process using robots for casting (where warranted by the type and size of foundry operations, as well as for other tasks) improves throughput, quality – i.e., uniformity and consistency – of the product, as well as energy efficiency, since the number of rejects is reduced.

Lost foam casting

For applicable foundries, this emerging technology has many advantages. It reduces costs and enhances design capabilities. It allows casting even very complex parts in a single pour, and more features can be designed into the casting. The parts produced with lost foam casting are highly accurate and the process does not leave appreciable blemishes or surplus metal that must be machined away. To introduce lost foam casting is a major technology change, but it has impressive economics stemming from a higher line throughput (by a factor of three or four), a much longer lifetime of lost-foam casting tools compared to conventional ones, and up to 30% energy savings.

Annealing in the mould

For some metals and casting designs, you may wish to investigate whether self-annealing in the mould is practicable. Then, subsequent heat treatment would be eliminated. This, too, could be part of a smart design.

2.1.4 Production scheduling, productivity and process control

We deal with production scheduling, productivity and process control throughout this guide, hence these few additional points.

During a normal workweek, production shutdowns on Friday night and start-ups on Sunday midnight or Monday morning cause energy losses in furnaces, holding furnaces, ovens, ladles, etc. With market demand supporting steady production and after considering the economics, some foundries adopted continental shifting. There are often overlooked benefits from *continental shifting* in maintenance and energy savings. The regular plant maintenance is done on Tuesdays, for example, and contractors are brought in at regular hourly rates, not at weekend premiums, as before. Secondly, the plant's power demand during the week is reduced, and an advantage may be obtained in cheaper weekend power rates.

In foundries that use electricity for melting, *analysing electrical demand* and the associated charges may provide a valuable input to production scheduling. Electrical demand charge may be considered a fixed cost on a monthly basis. Also, there is usually a predictable pattern to the general power demand in the plant. Often, there is a high coincidence of the melt deck demand combining at the same time with the general plant demand, with the resultant high peak demand penalty applying for the entire month. With another way of scheduling the production, it may be possible to shift the melting demand to another period of the day, thus reducing the peak demand charges. In fact, this could create a "free" demand zone, where the melting department could operate without incurring the excessive penalty.

A boost in productivity means better utilization of plant and equipment and the energy they require. Often, the hidden benefit of lower specific energy (and, of course, not-so-hidden labour costs!) due to higher productivity is overlooked. A case to illustrate the compounding of losses is the transfer of molten metal from the furnace to the pouring station. Often, there may be a distance involved, and the ladle holding the metal may not be properly lined and/or covered to limit the significant convection and radiation losses. To ensure that the metal is poured at the right temperature, the furnace may need to heat the metal to a much higher temperature. Not only is the energy wasted at the furnace, but also its lining is exposed to excessive wear, so productivity suffers in the end.

> Do you know the total cost of one hour of down time in your foundry?

Improved productivity resulted at an Ontario foundry when it converted to cell-based manufacturing, with good results. Among other benefits claimed are better awareness of quality, improved customer relationships, increased pride and process buy-in.

Use of robotics for repetitive operations, such as handling of forms and castings, finishing operations, cutting off gates and risers, removal of flash, etc., leads to an improvement in quality; can be combined with automated inspection, enabling product tracing; generally improves quality through the consistency and repeatability of operations; and increases productivity several times over the manual way.

Better process control also means better cost control that involves monitoring and accounting for energy costs. Further on we deal with how the use of electricity and fuels can be maximized with proper controls. More of the saved funds may be directed to energy efficiency improvements as a result.

Tip

Consider keeping employees informed about key economic indicators in the foundry: productivity, yield, safety, scrap, production plan attainment (in foundries with profit-sharing plans: monthly payouts, accumulated total). All this will help keep employees motivated and interested in improving results.

Very illustrative is a case of a large iron foundry in Ontario, where, at strategic points, per-pound costs of ingredients and other materials used by the foundry are prominently posted. The implicit message: do not waste resources!

2.1.5 Focusing on yield

> The primary concern of any foundry energy manager is to improve yield. This will automatically reduce internal waste of energy, raw materials and labour, and generate corresponding savings.

Casting yield has a great impact on the foundry's profitability. Casting yield should have already been considered at the design stage. The importance of improving yield to reduce energy consumption is well illustrated in iron foundries: the average 50% yield means that for each tonne of saleable casting an extra tonne has to be scrapped, handled, conveyed, re-melted and cast again.

Throughout the text of this guidebook, practices that result in better yield are mentioned. It was stressed that the road to improving yield starts at the casting and process design stage – see Section 2.3, "Foundry processes and equipment (page 50) and Section 2.2.1, "Managing electricity" (page 36), etc. – and we mentioned several factors that help to improve yield. One way to improve yield, which has been used in steel foundries, is to reduce the riser weight by using riser insulation. If the riser solidifies much later than the casting, it is probably too big; it wastes energy later on as well, with extra thickness to cut, and bigger scrap to handle and re-melt.

Other EMOs

Housekeeping

- Re-examine and question current practices for justification and EMOs.
- Try to optimize the layout of patterns in the mould.
- Try to fit a smaller pattern into the existing moulds.
- Check the risers' cooling rate with immersion thermocouples and record the temperatures to establish whether the rate of riser and patterns solidification is optimal.

Low cost

- Consider using oxygen enrichment in the melting furnace to increase the metal temperature and maintain chemistry: cold iron of poor chemical composition accounts for many rejects, dragging the yield down.

Retrofit; high cost

- Consider whether replacing your current hard-mould with high-pressure moulding and the appropriate equipment and process would be advantageous.
- As porosity and voids due to shrinkage and casting defects increase the rejects rate, consider a combination of effective metal degassing, fluxing and metal filtration to ensure pore-free and oxide-free castings.

2.1.6 Scrap and recycling

The highest-cost component in a good casting is the material cost. That, in turn, is influenced by the cost of the purchased scrap. Add to this the cost of energy, electrical demand, consumables and labour to arrive at the unit spout cost – the cost of castable metal per kilogram. The internal scrap, which is being returned to the charge, is valuable raw material, and should be treated as such. The cost of internal returns is often taken as equal to the spout cost, minus the credit given for the consumables, which was added to the molten metal previously. It means, that the metallic cost component is independent of either the yield or the proportion of returns in the charge: the high value of internal returns is being confirmed.

Scrap has, of course, a high energy and labour content because it went through the process once already. As well, it takes away from the yield. From these points of view, scrap represents big waste and a loss of sales opportunity. In Section 2.1.10, "Full cost accounting" (page 33), we argue that, in full cost accounting, scrap costs exceed the nominal spout costs. Efforts to limit the proportion of scrap at each stage of the casting process and convert it into saleable product should be made. When simple records are kept of the incidence and location of scrap, e.g., mould and core scrap, a picture will emerge of where to focus improvement efforts.

> The cost of internal returns is, in fact, more than furnace spout costs.

Other EMOs

Housekeeping

- Prevent scrap generation by maintaining proper process controls and correct operation practices (e.g., temperatures and degassing of molten metal).
- Recover all metal from rejects, cutoffs, shakeouts, etc.
- Reconsider the cost/benefits of currently selling internal scrap to outside processors.

2.1.7 Considering energy issues in change management

When changing a process or considering a purchase or modification of equipment, it is good practice to think about the possible effects the change may create in the operations. The terms normally used to describe this process are *change management* or *management of change*. Often, the review of the change is not done, or is done inconsistently and not systematically. The benefits are clearly the avoidance of unexpected nasty surprises later on. It is not always possible to rectify the shortcomings that emerge and which always require an additional expense of effort and money.

> The outcome of the change management process should be an orderly integration of the change into improved overall operations and advanced elimination of possible undesirable effects.

The "pause and think" process should have already been started at the conceptual stage by the person who proposed the change. Several criteria may be used, such as financial considerations, production capabilities and fit, labour, skills required, automation, maintenance, consumables, environment and energy aspects of the project. The evaluation of the critical criteria should follow the economic model of trade-off processes further described in Section 3.3, "Selecting and prioritizing EMO projects," page 92.

The accountability for managing the change process is consequently traced throughout the entire approval chain.

As the project is being further refined, and submitted for review and approval up the organization's ladder, the same questions should be asked by all those involved in the process. Chances are that the reviewers will bring different viewpoints into the evaluation and some overlooked points will get the attention they deserve. The proposed change should also be reviewed with regard to its interaction with other components of the operations. One of the tools that may be used for the collective review is a checklist. It can also be a capital requisition form (or engineering change order form, process change request form, etc.). These forms can be easily modified to include all the relevant project criteria, along with space for the reviewers' signatures.

In one company, a project is not approved until the proponent has exhausted all avenues to prove that, within the project's specifications, a better solution – including energy consumption – is not available.

In better-managed companies, the change management process is entrenched and governed by procedures to ensure that it is being followed consistently.

2.1.8 *Managing energy as raw material*

The overall management system of a foundry should have an energy component. That is, energy should be managed systematically and consistently. A disciplined and structured approach ensures that energy resources are provided and used as efficiently as possible. This is the principle of the U.K.-developed monitoring and targeting (M&T) technology of energy management. It is equally applicable to any other resource, such as water or product-in-process. Computerization made it possible.

M&T states that energy and other utilities are direct and controllable costs that should be monitored and controlled as any other segment of the operations, such as labour, raw materials and product distribution. M&T does not purport to attach a greater significance to energy costs than is warranted by its proportion of controllable costs. In foundries, though, energy is a significant cost component.

An energy-monitoring system enables the foundry's energy-saving program to target overall energy cost reductions on a year-to-year basis.

The application of the technology requires a change in thinking: to control energy implies responsibility and accountability by those in charge of the operations. The M&T process begins with dividing the plant into energy-accountable centres. The cost centres should correspond to the existing management accounting centres (e.g., melting, finishing, etc.) Within each centre, energy consumption is monitored; even individual key energy-using equipment can be monitored. This is dependent on the installation of adequate monitoring and measuring equipment, with input into a central controlling computer.

Data is continuously collected and analysed. Supervisors, maintenance personnel and operators have access to the information, which allows them to fine-tune foundry operations. Aberrations, such as excessive consumption peaks, can be investigated and addressed quickly.

Initially, the system will build a historical database – establishing a base to which the future improvements will be related. It will be necessary for each item monitored (e.g., furnace efficiency) to develop a suitable index against which to assess performance. For each index, a performance standard needs to be derived from historical data. However, it needs to reflect factors that can significantly affect efficiency.

M&T enables continuous, real-time monitoring, costing and optimization of foundry energy usage.

Typically, there may be absence of historical data because of the previous lack of instrumentation. In such cases, several months of data gathering will help to establish the standard. Managers involved must agree upon the derived standards. From the standards, progressive individual future energy consumption targets can be agreed upon by managers involved and be *perceived* as realistic and achievable. The targets represent improvements in energy use efficiency. More on target setting can be found in Section 3.4, "Developing energy management programs further" (page 99) and Section 3.5, "Implementing monitoring performance and continually improving" (page 101).

If resources do not allow it, start small: start gathering essential information manually, e.g., monthly, and acting on it. Based on the strength of your results, you'll soon be able to justify a better system.

Using the system can give you the ability to:

- Monitor electrical, natural gas/oil, water and compressed air usage rates under all plant operating conditions;
- Get energy costs per unit of production (e.g., a tonne of good castings) for each operating department;
- Process change simulation capability – the impact of process changes can be cost-calculated;
- Obtain information to determine effective electrical peak load control strategies;
- Obtain information to fine-tune the foundry's natural gas contract;
- Analyse the process to reduce fresh water consumption;
- Interlink the M&T system with a foundry-wide energy management computerized system, which includes process control condition monitoring and automation; and
- Monitor and troubleshoot the energy usage from a supervisor's home.

To get good buy-in, target setting should be also consensual.

M&T technology is a proven energy and money saver.

The cost of installation will depend on the extent of installed metering, the coverage desired, and the methods for recording and analysing energy use. The installation can pay for itself in increased efficiencies and savings in a matter of months.

M&T software and hardware packages are marketed by several firms. Also, NRCan's Office of Energy Efficiency provides workshops on M&T and other aspects of energy management. You will find information on those workshops at www.oee.nrcan.gc.ca/workshops

Other EMOs

Housekeeping

- Make employees aware of the energy and utilities costs; post information that shows trends; demonstrate how it impacts on the foundry's profitability.

Low cost

- Review the extent of monitoring and measuring equipment. Add to it the most important components now missing. Improve gradually in preparation for a full-fledged implementation of M&T.

Retrofit; high cost

- Install monitoring and measuring equipment on energy and utility streams in the foundry; purchase the M&T system.
- Integrate the M&T system within the total energy management system of the entire foundry.

2.1.9 Maintenance issues

Let us not overlook the *energy benefits of preventive maintenance*.

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

- Customer penalties for delays in just-in-time delivery environments;
- Higher labour costs that may include overtime to make up for lost time;
- Higher overhead costs; and
- Extra energy cost to keep the line on standby and hold the molten metal ready for casting, etc.

If you have not done so already, try to figure out the cost of various components for one hour of down time. It is likely that its energy component will be substantial. Planned preventive maintenance can help to reduce the unplanned down time and should be a routine part of overall operations. Preventive maintenance, therefore, is a very important part of an energy conservation program and energy efficiency improvements in any foundry. 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 include hand tools (particularly ones driven by compressed air). Apart from extending the useful life of the tools, this will result in a reduction of compressed air usage (thus, energy).

2.1.10 Full cost accounting

The foundry 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 2.2.1, "Managing electricity," page 36, and Section 2.2.2, "Managing fuels," page 40) and show 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 foundries with little or no energy-metering capabilities and an equal lack of interest in energy improvement. However, his or her professional interest may be aroused when shown Appendix 5.2 on energy benchmarks for Canadian foundries of basic metal cast types. Most if not all of these measures are controllable costs. To develop a set of key energy indicators like those in the Appendix, essential metering, monitoring and operational controls are required. Seeing the potential of the measurements and the magnitude of costs, the accountant would certainly support the energy improvement drive and help in preparing cost justifications for acquisition of the meters and the controls it would require. The rest is the work of the energy champion.

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

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

- Cost of electricity – total;
  - Consumption charge (time of day/week rates and charges);
  - Demand charge; and
  - Power factor penalty (if any);
- Cost of natural gas; and
- Cost of water (includes sewer charges).

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

- Energy (gas, oil or electricity) and cost of energy per tonne of melted metal;
- Average load factor;
- Average power factor;
- Furnace thermal conversion efficiency;
- Furnace demand as percentage of the foundry's total demand; and
- Compressor electrical costs, etc.

All such measurements can be used for setting standards against which new energy consumption (cost) targets can be determined. More on this is in Section 3.4, "Developing energy management programs further" (page 99) and Section 3.5, "Implementing, monitoring performance and continually improving" (page 101). Accounting for energy costs should investigate the impact of production practices on overall costs and help in determining optimal solutions. Examples are daytime versus nighttime melting and poor practices in keeping molten metal in the furnace longer or at a higher tap temperature than necessary. In scrap, energy cost will be equal to or slightly higher than in good castings. The subsequent processing of the scrap, however, effectively doubles the energy content per kilogram and causes other costs, briefly mentioned in Section 2.1.8, "Managing energy as raw material" (page 30). In full accounting for these "hidden" costs, the true extent of internal waste due to scrap will become obvious and will overshadow the nominal "spout metal units cost of scrap." Subsequently, management support and capital funds approvals should be much easier to obtain for:

> Full cost accounting, in the energy context, is akin to costing non-quality in the foundry's energy usage.

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

Other EMOs

Housekeeping

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

2.1.11 Implementing a management system

Often, an energy management program is a stand-alone undertaking. It would benefit from synergistic support of other management systems of the company, which share a common philosophy.

Quality or environmental management systems, such as those based on ISO 9000 (QMS) and ISO 14001 (EMS), introduce order and remove chaos – the daily "fire fighting" of recurring problems. Since energy consumption is among the most significant environmental aspects of any foundry, it makes the energy management program especially suitable for integration with the EMS. Under ISO 14001, a foundry must manage its significant aspects in a number of ways. One of them is setting objectives and targets, from which environmental management programs (i.e., action plans) follow. Reduction of energy consumption is a common objective, achievable through environmental (in this case, energy) management programs. The stress of ISO 14001 on continual improvement (taken up also by the new ISO 9000:2000) would strengthen this integration. It gives the energy management program, which becomes part of an overall environmental effort, the necessary regular attention and review by top management.

One should not overlook the fact that a vast majority of the 30 000 companies registered to ISO 14001 around the world (spring 2001) cited as a major reason for implementation of the EMS the internal cost benefits. No doubt that reasoning was behind the GM and Ford requirement that their suppliers will be registered to ISO 14001. The internal savings stem mainly from the environmental management programs that reduce waste and which the standard requires the organization to implement.

As of this writing, it is public information that at least one major foundry in Canada, Wescast Inc., has already been registered to the ISO 14001 environmental management standard.

A management system's advantages are in

- Methodical approach
- Consistency
- Orderliness
- Documentation

On average, the savings and improvements programs pay for ISO 14001 implementation costs in less than a year.

Other EMOs

Housekeeping

- Any organization will benefit from having up-to-date operating procedures and work instructions – as a part of a management system – to ensure consistency and standardization of operations. Better still is putting process documentation in flowchart form.

2.2 Utilities management

2.2.1 Managing electricity

Electric melting cost is by far the most important end-use point to control!

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

The electricity bill may have four components:

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

   The means to save:
   - Reduce the total electricity consumption (in kWh) in the facility; and
   - Shift energy consumption to a time when energy costs are lower.

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

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

   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 foundry is penalized when no production takes place (holidays or poor business).

   The means to save:
   - Reduce peak demand by:
     - Load-shedding – i.e., switching off non-essential electrical equipment;
     - Load-shifting – i.e., rescheduling operations so that some activities take place during off-peak periods;
     - Process improvements, which reduce electrical power requirements; and
     - Negotiating, if the utility allows it, for a 60-minute demand- setting period, instead of the 15-minute period.
   - Control demand with demand controllers – devices that reduce potential peaks and make a foundry's operations add load to the low spots. If you already have a demand controller, examine its function relative to a frequency of load factor peaks. Demand can also be controlled in multi-furnace operations by staggering operations and using new-generation power packs, which can split the power between the furnaces to control the demand effectively.

One of the main strategies to save power is to reduce the non-productive idle time in the furnace by reducing the extra delay in each melting cycle. This helps even out the load.

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

   Sometimes, kVA is used in the capacity charge. This 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.

   The means to save:
   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.; and
   – Installing capacitors in the electric system. The thing to watch for is that harmonics from electric furnace AC-DC-AC converters may trip or destroy the protection.

4. **Inducements** – e.g., offering different rates for blocks of consumption based on demand (e.g., 9¢/kWh for the first 100 000 kWh × 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 encourage a foundry to switch to melting at night, for example.

   The means to save:
   – Examine your electricity bill and try to renegotiate; and
   – 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 that have 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.

A large foundry in Ontario joined a real-time pricing program. Each afternoon, the foundry gets the price of kWh for the next day, starting at midnight. The operators enter the price into the system and then consider the quantities of iron in holding furnaces against the production schedule to decide on hour-by-hour usage targets. Since the power is (in this jurisdiction) at its most expensive between 10 a.m. and 11 a.m. and between 7 p.m. and 8 p.m. every day, they schedule melting to suit, e.g., shifting it to night melting, with corresponding reduction during the daytime.

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

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

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

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

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

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

In conserving electricity, focus on where the potential savings are! Table 3 illustrates where foundries use electricity.

TABLE 3:
Where foundries use electricity

Foundry type	Melting		Motors		Compressed air	Lighting
	Demand	Consumption	Demand	Consumption	Demand and Consumption	Consumption
	% kW	% kWh	% kW	% kWh	% total costs	% kWh
Iron (14 foundries)	78 (68–89)	66 (54–84)	40	30	15.1 (3–44)	4
Steel (16 foundries)	68 (59–88)	49 (43–65)	35	47	12 (4–21)	4
Bronze and copper (15 foundries)	59	38	–	57	(8–29) (up to 70% of total power costs in gas melting foundries)	5

Composite table from works of L.V. Whiting, based on surveys of Canadian foundries, 2000

In a large Ontario foundry, the monitoring of electric energy losses within the foundry is now a way of life. Parameters such as kW, kvar, kVA, PF (power factor), MWh, frequency, demand variations and total harmonic distortion are monitored on a shift basis. The ECAM® system used has a troubleshooting capability.

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 motors. These motors have efficiencies above 93% (in dependence on the motor horsepower: the higher, the better efficiency). The summary replacement of running old motors with the high-efficiency 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 or idling motors waste electricity and cause poor power factors. That is frequently the case in motors operating sand mullers, baghouses and air compressors – usually the biggest in the foundry. These motors, among the hardest working, are especially susceptible to burnouts by electric induction or arc furnace harmonics.

Other EMOs

Housekeeping

- 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 foundry operations in view of the factors involved 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.
- Consider requesting help from your local utility or from NRCan's CANMET. Computer-modeling programs are available that show how furnace operating parameters affect operating costs.
- 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 foundry need to be upgraded.
- Use your electric utility as a resource: it can make suggestions as to demand reduction alternatives, offer points for metering and the way to measure consumption, and possibly lend a load analyser.
- Maintain and calibrate automatic controls on all equipment.
- Schedule powering of electric induction furnaces in sequence so as to avoid creating power demand peaks unnecessarily.
- Control harmonic distortion passively and upstream; specify it in new equipment buying standards.

> By understanding how the melting operation affects costs, the furnace operators can bring in big savings!

Low 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 induction furnaces. The software serves as an electricity and process management tool. It monitors power usage instantaneously and adjusts to a set target for maximum level of power it can use. It governs the consumption through a programmable logic controller (PLC). It can express real and predicted usage of power in kWh/t of melted iron, in kWh/t of finished product, and also in terms of costs; e.g., PowerPlusReporter® software; environmental and energy management programs from E2MS Inc.
- Consider conducting thermographic inspections of furnaces, ovens and ladles for heat loss, and for detection of electrical hot spots, e.g., in couplings and contacts, which indicate mechanical sources of loss.

Retrofit; high cost

- Control furnace harmonics that can interfere with and cause burnouts of motors.
- 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 an Ontario foundry, power factors close to unity, i.e., 0.98–0.99, are routine!
- When installing an energy management system, choose one with both analytical and reporting capability.
- Consider installing a power monitoring system with monitoring and targeting methodology to manage electricity consumption in the entire foundry.

A full one third of the foundries surveyed in 2000 had power quality problems from induction and electric arc furnaces, particularly when combined with older power supply systems. The harmonics generated caused damage to capacitors installed to control the power factor, tripped fuses, burned motors and overheated equipment. It is essential to control harmonics.

2.2.2 Managing fuels

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

While the marketplace for the natural gas industry has long been competitive in the three of Canada's western provinces, customers in Ontario and Quebec are getting used to deregulated market conditions. Apart from New Brunswick and Nova Scotia, where an alliance was formed for natural distribution rights, there are few if any gas lines in the rest of Canada. Natural gas prices rose sharply in 2000. Energy efficiency and demand side management (DSM; described in Section 2.2.1, "Managing electricity," page 36) will be increasingly important tools for foundries in managing costs. Large users of natural gas are purchasing gas on the spot market and are using software to manage the task for maximum financial benefit. Although escalating gas costs are a major factor in energy budgets, some larger companies have managed to offset them by installing combined heat and power (CHP) cogenerators for generating their own electricity and selling a potential surplus to the distribution net. This option is now being intensely scrutinized by many companies.

Many foundries in parts of Quebec, the Maritimes and northeastern Ontario, depend on oil for their energy needs. To change one source of energy (oil, gas, electricity) for another is always expensive and difficult to do in an established foundry. Many aluminum foundries, however, made the switch from gas to electricity, and the necessary investment (roughly $500,000 for the purchase and installation of a medium-sized induction furnace). They justified it on the grounds of quality, and about 7% savings from gas-melting losses. In addition to better metal yield, the melt cleanliness improved and hydrogen pickup was reduced.

Burning of oil may present special problems. It requires storage systems that must meet rigorous criteria to prevent environmental contamination from overfills and leakage. In the winter, the lines must be heat-traced to prevent gelling of the oil or precipitation of waxes. Due to high combustion temperatures, the burning of oil tends to produce oxides of nitrogen (NO_x). The potentially high sulphur content (especially in heavy or "bunker" oil) may preclude utilization of flue gas economizers due to corrosion problems arising from condensation and formation of acids from sulphur oxides (SO_x).

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

- **Gas/oil delivery system**

  Is the delivery system tight, without obstructions and leaks? Gas lines, many of which may be decades old and buried underground, may have corroded and have leaks. To find out whether they are leaking, during a no-production period, record the gas meter reading and check it again after 12 to 24 hours. Providing that not even the gas water heater was on, there should be no difference. Account for legitimate gas consumption for space heating, etc., by estimating the consumption based on the plate information. Otherwise, leaks may be indicated, and work should start on uncovering their source and fixing them promptly (safety may be involved!).

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

- **Combustion**

  Oil and gas furnaces very frequently lack adequate controls. Poor control of air/gas ratio results in wasted energy, frequently excessive temperatures and metallurgical problems. Consider replacing burners without adequate means to correctly control air-to-fuel ratio. Ideally, air-to-fuel ratio controls should also account for temperature of combustion air, which affects its density (which depends on time of the day and seasons), to provide a correct burning regime. Fuel gas analysis will show the correct composition. For natural gas, under equilibrium conditions, the flue gas composition should show close to 12% CO_2, about 20–22% water vapour and the rest nitrogen. Lower percentages of CO_2, and the presence of carbon monoxide (CO) and hydrogen, indicate poor combustion (reducing fire) and chemical energy losses in the two escaping gases; a portion of the gas has been wasted. On the other hand, in excess air supply conditions, all the gas will be burnt, but the analysis will reveal the presence of oxygen. Again, energy was wasted, this time by heating the extra air passing through the furnace.

The issue of burner adjustment is just as serious in heat-treating ovens, where multiple burners may be used. Maintenance and burner adjustments also tend to be neglected. The remedy lies in upgrading your burner to an energy-efficient type with good controls (also see Section 2.3.3, "Melting," page 51), regular maintenance of the burners and regular flue gas analyses.

- **Airtightness of the furnace chamber**
  Air ingress into the furnace (heat treatment furnace) causes significant loss of energy. All that extra air needs to be heated to maintain the proper furnace chamber temperature. Air ingress may produce "cold" spots and quality problems as well.

- **Thermal losses – conductive, heat sinks and radiation**
  For thermal losses and conductive heat sinks, it is a question of adequate insulation and furnace or ladle lining with the right type of refractory materials. If dense firebrick is used for lining the furnace, it needs to be installed in adequate thickness to limit the heat conductive losses. The large mass of the firebrick, however, acts as a heat sink. It is expensive to heat up and keep at the right temperature. 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. (For more information, see Section 2.3.3, "Melting" (page 51) and Section 2.3.9, "Heat treating" (page 70).

  The radiation losses are serious in melting furnaces (e.g., electric arc or induction furnaces) where they occur through open lids, open dross removing or slagging doors, from ladles with no or inadequate covers during heating, and especially during molten metal transfer (see Section 2.3.3, "Melting," page 51).

In foundries, the use of *steam* is usually limited to heating or conditioning purposes. Except for small-output boilers, which may be heated by electricity, most boilers and heaters are usually gas- or oil-fired. The same principles of proper combustion apply to boiler burners, as discussed above, and under melting, heating and heat-treating. Steam generation requires a separate water treatment system and an effective collection and return system for the condensate. Attention to air elimination from the steam, boiler and pipes insulation, and steam traps maintenance are also important points in making the system efficient. Some of the EMOs, specific to steam boilers, are listed below.

Other EMOs

Housekeeping

- Maintain the burner setting in proper adjustment under a regular maintenance program.
- Control the flue gas composition, checking for oxygen and CO levels regularly.
- Prevent air ingress: maintain the airtightness of the furnace/oven, caulk and seal cracks, and maintain seals on lids and opening covers.
- Clean and maintain heat-transfer surfaces in a steam boiler.
- Control the quality of boiler feedwater and minimize the blowdown.
- Inspect boiler insulation; stem pipes and condensate return pipes insulation.
- Maintain steam traps to minimize steam/condensate loss.
- The gas company can be approached with a request for a loan of extra gas meters for sub-metering major gas-burning equipment.

Low cost

- Consider installing gas flow meters to manage the consumption of the major gas-using equipment – such as furnaces and ovens.
- Monitor and control the inside furnace/oven 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 oil burner maintenance, efficiency testing and off-gas analyses.

Retrofit; high cost

- Consider repositioning upgraded burners in the furnace. A foundry in Quebec did this. It improved furnace heat distribution and achieved natural gas savings at the same time.

2.2.3 Managing compressed air

Compressed air is the most expensive utility in a foundry. The foundry industry uses a great deal of compressed air for production purposes. It is a safe and convenient form of energy, frequently taken for granted and overlooked as a possible savings option.

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

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

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

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

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

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

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

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

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

Your 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 savings options. However, for best results, do not just consider it as a sum of individual components such as compressors, dryers, filters, coolers and auxiliary equipment.

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

- Analysing demand and matching capacity to demand;
- Controlling peak demand events;
- Correcting poor applications and waste in using compressed air;
- Identifying and correcting leaks;
- Controlling and managing the entire system;
- Optimizing the maintenance program;
- Sensitizing users to correct practices and savings opportunities; and
- 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* ($), *low cost* ($$) or *retrofit* high-cost capital items ($$$).

Analyse the demand

- Identify critical users and analyse their needs regarding compressed air pressure, volumetric flow, frequency of use and duration of the usage events. That will help in designing eventual 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, cooling by blowing compressed air, and open blowing, with other equipment giving the same results but at lower costs ($–$$).

- Do not cool hot castings with compressed air. If need be, install a low-pressure blower for the job.

Eliminate waste
- Generate compressed air at the lowest possible pressure suitable for the task ($).
- Never generate at too high a pressure only to reduce it to a lower operating pressure later ($).
- Do not compensate with higher pressure for poorly maintained air tools or undersized air distribution lines ($).
- Consider using high-efficiency blow nozzles (reducing air consumption by at least 50%) ($).
- Consider using a different nozzle type and configuration when blowing off water after annealing ($–$$).
- Minimize losses of compressed air in various pieces of measuring and controlling equipment using it: install section valves ($$).
- Consider dual pressure control for off-shift operation ($$).
- Switch off compressors when not needed ($).

Eliminate leaks
- Think of compressed air as you would water: stop the leaks at once ($).
- Use the listening method after normal working hours ($).
- Invest in an ultrasound listening device to identify leaks (e.g., Ultraprobe 2000™ ($).
- Consider purchasing a compressed air leak tester to detect pressure drops because of leaks and to measure the compressor capacity ($$).
- Consider implementing an automatic leak-measuring process, to be done on weekends, through a computerized control, regulation and monitoring system and installation of enough section valves ($$-$$$).

Tip

A leakage reduction program must be ongoing to be effective!

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" ($$$).
- Use the central control, regulation and monitoring system to start/stop the compressors at pre-determined times during the week. One such program is XCEED™ Compressed Air Management System by Honeywell ($$$).

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

Train operators
- In order to achieve operational savings and quality improvements, users and operators must understand the system and be aware of its operating costs ($).
- Delegate responsibility for ensuring that the compressed air system has no leaks ($).

- Request that operators 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 ($$).
- On a monthly basis, monitor, e.g.:
  - kWh/total number of labour hours in production;
  - kWh/m^3 (i.e., compressor efficiency); and
  - m^3/total number of labour hours in production.
- In addition, do the same monitoring in terms of dollar costs.

Other EMOs

Housekeeping

- Maintain air filters.
- Eliminate redundant couplings and hoses as potential sources of leaks.
- Remove obsolete compressed air distribution piping to reduce pressure loss, leaks and maintenance costs.
- When reciprocating and screw compressors are used in parallel, always maintain screw compressors at full load; when partial loads are required, shut down the screw compressor and use the reciprocating compressor instead.
- Avoid using compressed air when low-pressure blower air will do the job as well.
- Ensure that 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 methods.
- Review the compressed air system and air uses annually – develop a checklist to simplify the task.
- Keep all air tools, connectors and hoses in good repair.

Low cost

- Draw intake air for both compressing and compressor cooling (if air-cooled) from the coolest location outside.
- Replace older, high-maintenance air-engine driven equipment with a 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 on the investment ranges from 8 to 24 months.
- Install a large compressed air accumulator tank to reduce compressor cycling.

Retrofit; high cost

- Install a system pressure regulator to eliminate artificial demand by stabilizing pressure at the minimum required level for production. Note: typically, energy savings of 10% are achieved (e.g., XCEED™ Demand Expander).
- Consider installing rotary drum air dryers, where the heat generated by the air compressor is used to continually regenerate the air dryer desiccant, and no compressed air is consumed.
- Consider installation of an airtight plastic pipe distribution network to replace old steel pipes and corroded and leaking circuits.
- For smaller or occasional compressed air usage, consider using a combustion engine-driven compressor unit, which provides a less expensive energy input, 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 a more efficient type, e.g., freeze dryer or rotating drum dryer.
- Consider fitting a variable speed drive to your fixed-speed compressor (typically, payback of less than two 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.

Additional information

An older technical manual, *Water and Compressed Air Systems* (Cat. No. M91-6/12E), is still available at NRCan – tel.: (613) 996-6220 – and remains a good reference. For a complete listing of other energy management manuals, see Appendix 5.7. The Web site at www.knowpressure.org may also furnish additional information.

2.2.4 Managing water

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

The effort to manage water should start with preparing water balance. 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 commonly the case in many small foundries, use estimates. The mains water pressure, known diameter of the mains, and often a five-gallon bucket and a stopwatch can be used as the improvised tools to provide a reasonably accurate picture. Water temperatures should be measured. The information should be analysed for wasteful, non-productive usage and excessive flows. A picture should emerge about what stream can be used where, whether water reuse is possible and for what purposes, and where there is a potential for heat transfer. With successful launching of water conservation initiatives, justifications may become available for installing more water flow meters elsewhere in the foundry.

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

Annual water costs in a foundry 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 foundry. In the processes, water discharged from one operation could be piped into wet scrubbers, or mullers for sand conditioning, etc.

A leak equivalent to a 6.4 mm (1/4 in.) stream of city water will waste about 2200 m^3 annually, at a yearly cost of some $2,100 (prices in 2000).

A foundry may have several water systems, such as process cooling water, potable water, domestic hot water, boiler feedwater. They have similar inefficiencies and, because of the water heat content, similar energy management opportunities. Cooling water is used for mould sand reclamation, electric arc furnace or induction furnace cooling, as a heat extraction medium in furnace or oven flue gases, in shell mould and shell core machines, in mould units' hydraulic systems, in permanent moulds cooling, in quenchers, in air compressors, etc. The water should be recirculated as many times as possible through these operations to prevent waste. For that to occur, however, the water itself needs to be cooled down.

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

Closed-loop mechanical water chillers use the refrigerant condensing coil to extract the heat. They conserve water, produce very cold water and eliminate the need for water-conditioning chemicals, but they are more expensive to install and run. In a foundry, they may find an application for induction furnace coil cooling, for example, where the predictability of the water incoming temperature allows for close control of the furnace.

The cooling of air compressors also requires close control of the cooling water temperature. 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. The hot water energy potential can provide useful service in space heating, steam generation, and tempering make up air as well as through the use of heat pumps for air conditioning.

Other EMOs

Housekeeping

- Examine water use patterns and reduce water consumption to the minimum necessary.
- Maintain the system; stop leaks promptly.
- Reduce pump-operating time where possible.
- Instil good housekeeping practices in all employees.
- Do not let the eyewash fountains run as a drinking water source; provide drinking fountains instead.
- Remove stagnant, redundant branches of the water distribution network.

Low cost

- Re-use and/or recirculate cooling waters and process waters imaginatively (e.g., use a pump seal water to serve as an air-conditioning unit). Use process or cooling water as a heat-exchange medium in your ventilation or heating system. Consider placing a water/air heat exchanger system inside the foundry to help with the heating load in the winter, etc.
- 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 fibre reinforced plastic off-the-shelf tank or a second-hand vessel for the collection and use of the water later. Use these collection vessels to even out the supply/demand ratio in your water *multiple* reuse projects.
- Reduce water heat loss or gain by proper insulation.
- Install water system expansion tanks on closed loop systems, to serve two purposes: when the water is hot, waste through relief valves will be prevented. When the water is cold, the contracted volume would normally demand make-up water to keep the system filled.
- Reduce friction losses and the associated pressure drops by streamlining and correct-sizing of water pipes.
- Review correct size and choice of water pumps.
- Install water-flow regulators for sanitary uses; delayed closing or timed flow taps on hand wash basins and reduced-flow shower heads.
- Install the European-type on-demand gas water heaters for sanitary use (as one foundry did).
- Limit the use of make-up water to critical tasks, such as cooling of fan bearings in heat-treating ovens.

Retrofit; high cost

- Use a closed loop, "dry" cooling system for electric induction furnace cooling, cooling of permanent dies, etc.
- Implement a water system with multiple re-uses of process water on the heat cascading principle.
- 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 the waste-water evaporator, for sludge disposal.

2.3 Foundry processes and equipment

It may be useful to repeat a few basic relationships:

- The energy to produce a tonne of good castings is the foundry's total energy consumption divided by the tonnage of castings shipped;
- The furnace production is the total energy divided by the tonnage melted; and
- The overall yield is the ratio of the energy in good castings and in furnace production.

Adding to the melting energy, the foundry's other energy intensive systems, such as compressed air and transport systems for molten metal, sand, castings and scrap, multiply the energy content in the casting. In the following, we shall examine these systems briefly.

2.3.1 Raw materials

Other EMOs

Housekeeping

- Support cost-consciousness in your employees. On posted signs throughout the foundry, at strategic locations, show costs of raw materials (sand, silicon, ferroalloy admixtures, etc.) in $/kg. Make employees aware of how much is consumed – and wasted – through poor housekeeping, and at what cost.
- Ensure adequate inventory with due consideration to delivery lead times – running out of an item will certainly result in energy losses as well.
- Keep the inventory of raw materials current.

Low cost

- Try to keep raw materials dry and, if possible, "warm" inside, particularly scrap, in order to reduce the temperature gradient for preheating/drying or melting; keep the scrap bay doors closed.

2.3.2 Process and material flow

Time is money. Time losses caused by a poor layout of process equipment, cumbersome operating procedures, a multi-layered organizational structure, delays in transporting materials, molten metal and parts, also incur productivity losses and additional energy costs. Even in established and well-managed foundries, opportunities may be found for process streamlining and simplification, with attendant savings and productivity benefits.

> Take a process-based – not department-based (!) – view of operations.

What are the tools to use? An experienced foundry worker may have an instinctive feel for the existence of process bottlenecks in the foundry. In other circumstances, a "rough and dirty" time and motion study will uncover likely shortcomings. In the search for solutions, keeping an open mind and challenging established practices help. So does simple flowcharting of the processes. Pencil, paper and input from knowledgeable operators and staff are all that are needed. When examining a process flowchart, shortcomings, redundancy, duplication of effort and waste may become readily and visually apparent. Consider each activity and process step in terms of supplier-customer relationships. In large foundries, and for complex projects, the use of process simulation software could be employed to find optimum solutions.

Is it really more profitable to rush off with a ladle of poured metal from an electric arc furnace than to have it charged first for the next heat? Do we have to transport the charge bucket over a furnace to reach the next one? Is using the pneumatic system for transporting moulding sand a smart way to do it, considering the high maintenance and high energy costs? Can transporting distances and timing sequences be optimized?

Once we come up with ideas for process improvement, let us subject them to critical evaluation, described in Sections 3.2 to 3.5 (pages 91-101).

Monorail transport system

Foundries with ladle transport by gantry cranes can learn from a galvanizing foundry in the Netherlands. For transporting large parts to be hot-galvanized, a single 5-t gantry crane system was used. This was causing considerable waiting times (and hence heat/energy losses). A new monorail system with a bypass and carrying three gantry cranes was installed. The new arrangement allows the products to be moved independently and simultaneously, and allows the gantry cranes returning to the beginning of the line to pass the other ones. Energy savings alone allowed a 3.5-year payback, but operational advantages (e.g., productivity improvements) reduced it to 1.7 years.

2.3.3 Melting

As shown in Appendix 5.2, Energy benchmarks in foundries, melting is the major energy user and cost factor. It is important to quantify and understand melting costs in relation to operating practices, and equipment and material costs. Because of its importance, each furnace should have an energy balance undertaken

The opportunities for energy savings in melting are in:

- Preheating of the charge;
- Proper selection and adjustments of gas (oil) burners;
- Furnace insulation and maintenance;
- Monitoring and control; and
- Proper choice of electric melting technology.

Preheating of the charge

The preheating of the furnace charge is done for these reasons:

- Safety – to dry off and degrease the charge before melting;
- Process throughput – the energy input to the furnace is decreased, thus the melting is faster and the melting capacity increased; and
- Cost – the heat from the furnace off-gases can be used for the purpose, or natural gas is used instead of electrical power (if still lower).

Overall, the total energy costs for the melting operations are reduced. Should gas prices exceed those of electricity, the justification for using the preheater should be based on the net increase in melting throughput. In electric induction melting, the demand charge can be reduced substantially by preheating.

The operation of the preheater should be synchronized with the furnace. Preheating should not lead to oxidation losses (by excessive temperatures or holding times of the charge in the preheater), and the transfers from the preheater to the furnace should be quick to minimize the transfer heat losses.

Preheating is normally difficult to justify for electric arc furnaces.

Fuel-burning melting

There have been improvements in *heat recuperation* from flue gases for the preheating of combustion air (usually not more than 600°C), consisting of high-temperature ceramic recuperators and burners, with the recuperator becoming an integral part of the burner itself. These developments enable about 30% energy savings over combustion with no preheating.

Recently, there has been a shift from recuperation to *regenerative burners*, which usually work in pairs and are fired alternately for only a few minutes. During the burn, high-temperature flue gas is passed through a porous bed of ceramic material around the burner, which is not on. Then the cycle is reversed, the idle burner is fired and the combustion air is drawn through the ceramic material, which stored the heat in the previous cycle. Preheating to within some 150°C of furnace chamber temperature is possible, with the generally reported resultant savings of over 50% (compared to cold-air burners).

Newly developed low-NO_x regenerative burners significantly reduce the NO_x levels normally created by burners of this type; the energy efficiency is maintained.

The proper positioning of the burners in the furnace can also increase energy efficiency incrementally, by creating high turbulence of the burning gas within the furnace, which aids the heat transfer as well as more complete combustion of the fuel.

After the ramp-up to the desired metal temperature, gas or oil burners are usually throttled back by limiting fuel and air supply. This may throw the burners out of adjustment. The use of microprocessor controls allows the burners to be pulse-fired, at a fixed high firing rate, to achieve the reduction of heat input in a better-controlled way.

To counteract the negative effect of air infiltration into the furnace, and/or to increase the molten metal temperature more quickly, oxygen trim is used in the burners.

As with all combustion systems, the optimum performance of a burner is dependent on maintaining a proper air/fuel ratio, which requires regular monitoring. If the excess air levels are raised, the specific energy consumption of the furnace goes up as well. Automatic flue gas analysers for excess oxygen are available.

In terms of energy losses from fuel-fired furnaces, the heat discharged in the flue gases represents the greatest loss. Heat recovery should then be an important EMO.

The benefits of improvements to fuel-fired furnaces can be estimated with a simple formula:

$$\mathbf{E = R \times S \times N \times F}$$

Where: **E =** energy cost savings in \$/year
R = burner rating (GJ/h)
S = expected percentage energy saving
N = number of operational hours/year
F = fuel costs (\$/GJ)

Furnace insulation and maintenance

Heat losses due to radiation and convection from a furnace (or oven or dryer) must be minimized.

The losses can be high if the enclosure is not properly maintained. Heat loss can occur because of deficiencies such as:

- Damaged or missing insulation;
- Damaged, warped or loose-fitting furnace doors and missing sampling covers and other openings in the furnace enclosure that allow ingress of air to cool the inside furnace temperature; and
- Excessive heat transmission through the furnace structure.

The furnace structural heat losses are further increased by intermittent furnace operation.

The use of low-density, low thermal conductivity and low thermal mass ceramic fibre materials as a hot face lining can minimize the loss of heat to the furnace structure. The ceramic fibre has, of course, the disadvantage of low mechanical strength, hence a low durability. To counteract this, it is sometimes used in sandwich fashion with other refractory materials, such as high-density brick or castables, insulation brick or low-temperature (LT) boards. However, the ceramic fibre has a thermal shock resistance, which is much better than that of other types of refractories. The lining can withstand very fast heating and cooling cycles.

A thermograph is an extremely useful tool in discovering areas in need of (additional) insulation or air leakage control.

Controls

The use of PLCs; direct temperature measurements of the molten metal (this being more important than the temperature of the furnace chamber); use of zirconia-based oxygen probes inside the furnace; use of oxygen trim, flue stack gas analysers and flue stack damper control to maintain the desirable furnace chamber pressure; and computerization of melting operations – all these measures help to reduce energy consumption.

Electric furnaces

Because of easing in regulation, little or no emissions generation during melting, metallurgy considerations, and the ability to provide high energy density, electricity is often the preferred energy source. The choice of furnace depends on the application, and the acquisition should have been cost driven. Hence, once installed, the foundry must maximize the electric efficiency of the furnace. Some of the methods are also described in Section 2.2.1, "Managing electricity" (page 36).

Electric arc, using DC, achieves high temperatures and short melt times. Here, the supplemental use of oxy-fuel burners in electric arc furnaces contributes to additional and substantial energy savings. The best thermal efficiency for some metal melting applications has *electrical resistance melting*. It achieves close to 100% conversion of electricity to heat. Electrical *induction furnaces*, using AC, are widespread as channel or coreless types, with efficiencies in the 50-70% range and heat losses to cooling water accounting for 20–25% of the total input.

The electrical costs consist of the consumption cost for melting and overnight and weekend shutdown holding, and the demand costs. Once these costs are analysed and understood, it becomes clearer how to control them.

Electric arc melting

The very efficient electric arc melting practice is used in iron, grey iron, ductile iron and steel melting, where the specific energy consumption of about 550 kWh per tonne is considered a good benchmark. Electric arc furnaces require high voltage supply and installation of primary metering and demand controlling equipment. EMOs in electric arc furnaces are related to:

- The correct installation and positioning of the grounding straps or rods at the bottom of the furnace;
- Electric power supply and distribution;
- Power demand control; and
- Operation practices:
  - Speed of heat;
  - Arc regulation;
  - Delays;
  - Operator's activities; and
  - Problem analysis.

Heat transfer at the arc will be most efficient under full power for long arcs, to speed up the boredown and meltdown. This is helped by automatic regulation of the electrode movement to optimize electricity conversion. A regulating system, which is not optimized, wastes energy and lengthens the heat. The equality of the power supply can also affect furnace efficiency and electrode life, should the power feed characteristics be changed by the electric company. It pays to talk to your utility.

Unnecessary *delays* cut into the furnace utilization and are a major source of energy waste. The waiting time should be only as long as necessary (e.g., for furnace cleaning after the pouring). The delays are very much influenced by the operators' practices: all preparatory tasks (e.g., lance and electrode preparation, consumables readying, removal and emptying of slag pot, cleaning of the tap hole and the spout) should be done in advance of the pouring and charging, while the heat is on and the meltdown progresses. As well, the ladle should be in position, just in time, ready for tapping. Consider whether – contrary to the usual sequence – charging the furnace first and then removing the ladle by the crane would improve the furnace utilization and throughput. If it is possible, carry out furnace maintenance in the off-shift.

The electric arc furnace is a very intensive operation. It is good practice to maintain a *daily log* with the essential information about the charge, heating characteristics, electrode breakages, etc. and regularly analyse the record in search of clues for *preventive action*.

Water-cooled panels are now often installed in the furnace roof and areas of severe wear in the sidewalls to protect the refractory. Contrary to expectations, the specific energy consumption did not increase appreciably during the heat (perhaps only because of water circulation). The refractory life increased by more than half, and there were slight reductions in cycle time (8%) and overall heat time. The hot water should present additional opportunities for waste heat utilization.

Electrical induction furnaces

L.V. Whiting of NRCan's CANMET coined the term "hurry and wait" for the wasteful practice of fast melting at maximum power, regardless of metal demand, only to incur long delays in excess of those that are part of a normal cycle. This practice had the highest electricity costs. In contrast, the "no wait" mode reduces the power in proportion to the average melting rate as the daily melting period increases. This had the minimum melting costs. A comparative study of many foundries showed results, which are interesting to any foundry manager. Apart from other influences, i.e., production scheduling, etc., *the specific electricity consumption – and the cost per tonne – decreases with*:

- Lowering the melting power, resulting in a longer melting period;
- Increasing the furnace utilization rate in a day;
- Increasing the furnace charge size (often 20% below the optimum);
- Reduction of extra (i.e., unnecessary) delays;
- Reduction of lid-off periods;
- Lowering the molten metal temperature;
- Increasing the tap size;
- Lowering the holding power;
- Higher induction coil efficiency; and
- Controlling power demand.

Lowering the melting power has an additional benefit of reducing the furnace lining erosion, due to less vigorous inductive stirring of the charge, which reduces the lining maintenance requirements.

A *coreless induction furnace* loses energy in three ways:

- Radiation – losses associated with the furnace lid opening;
- Conduction – through the furnace structure; and
- Slag/dross skimming.

For a medium-sized induction coreless furnace melting iron, the average radiation loss will be equivalent to 10–15 kWh for every minute the cover is open.

The induction coreless furnace usually operates on a continuous batch cycle: a molten metal load is tapped out, and the equivalent-mass charge is dropped in. The tap and charge size should be of sufficient volume to maintain the level of liquid metal above the upper edge of the induction coil. This enables the coil to use full power. During charging, the furnace lid is swung away, and instantly large *radiation heat losses* occur. These will have to be compensated for, by the additional power at the furnace transformer. Using the following example, try to estimate the yearly cost of uncovering the furnace.

It is important to review your charging and tapping practices in order to minimize the number of times the lid is off during the melt and the duration of the uncovered periods. For example, when sampling the molten metal or measuring its temperature, instead of swinging the lid open to do so, make a hole in the cover (normally stoppered) and take samples through it.

Conductive losses can be minimized by proper use of refractory materials in the crucible of the furnace (dealt with elsewhere in this guidebook) and through maintaining a good, tight fit between the cover and the furnace body. It helps to have a spare, well-maintained lid for a quick exchange when necessary.

Slagging or dross removal can be optimized with a power skimmer or by widening the furnace spout to pour out the slag into a transfer ladle for easier skimming. The same radiation losses also occur during the slagging operations through spouts and skimming doors. Again, the access to the furnace through these openings should be kept to an absolute minimum. There should be a good seal on the doors and spout covers when closed.

Electrical channel induction furnaces incur additional energy losses: the melting is done in the furnace's channel, and to make the furnace work there must be a "heel" of molten metal left in the furnace in between the charges, as well as over the non-production periods, albeit at a lower power setting. This also enlarges the convection structural losses.

Molten metal holding

Whether or not to install a holding furnace should be the subject of a thorough economic analysis of production and fuel/power consumption patterns and costs, to determine its feasibility. Storing molten metal in holding furnaces is frequently practised as a way to smooth out the production curve, solve scheduling difficulties, and allow casting operations to proceed while the batch furnace is readying the next pour. There is also the cost-avoidance element involved in such decisions – the need for an additional melting furnace when expanding production can be postponed.

Storing the molten metal is equal to storing energy. It can shave off the power demand peaks and level the electricity demand, and take advantage of reduced rates during certain times. The result is molten metal available for production at reduced energy costs.

The following are just a few examples of energy-efficient measures taken and innovations implemented in melting metals in various foundries.

Refractories

Ceramic insulation

Ceramic insulation can replace refractory bricks in some applications, e.g., furnace lids, car bottom furnaces, etc. It stores less heat, loses less heat, and does not require as much heat to warm up as the firebrick. This is helpful when the furnace is used intermittently; it can be shut off between the loads. Apart from conserving energy for heating, it helps to control inside temperatures more closely. In the installations studied, the lifetime of the insulation was given as 15 years and the electric power savings were in the 6–26% range.

Ladle, lauder and holding furnace lining

In the maintenance and relining of ladles and lauders, the traditionally used refractory materials required labour intensive work and long drying times. In addition, the rather poor insulating capacity of the material required constant and intensive heating when not in use. Among others, a foundry in the U.K. switched to a new lining material with low-density, low thermal conductivity and non-wetting characteristics.

The lining can be ordered in form-fitting shapes and installation is relatively simple. The benefits are labour and time savings, and substantial energy savings. As opposed to the former requirement of keeping the preheating burners for the ladles on for 24 hours a day to maintain the ladle temperature, the new lining allows preheating of the ladle for only 2.5 hours at the beginning of the work-week. After that, the excellent insulating characteristics of the material obviate the need for preheating. As well, the molten metal tapping temperature could be lowered, because the transit temperature losses were substantially reduced (e.g., on an average from 50°C down to 15°C). The linings can typically last 12–18 months. In this particular installation, the best news was that the payback was a mere nine weeks.

An eastern Ontario foundry also eliminated its core furnace and ladle refractory bricks with boards, with similar results in energy savings.

Preheating

If the scrap contains water when it is being charged into a furnace, then the instant evaporation of the water upon contacting the molten metal can explode with sufficient force to inflict damage or injury. The standard practice is to use gas preheaters to dry the scrap, but the size and type of standard equipment does not always match the requirements of smaller installations. An Ontario foundry installed an efficient scrap iron preheater. To control air emissions from the pre-heating of wet and oily iron scrap, an afterburner was also installed. With it, the foundry was able to meet or exceed the emissions standards. Although with the afterburner the energy saved was only 11%, the preheated charge reduced melting times appreciably. This enabled the production to increase by 17%. The project was partly funded by the Industry Energy Research and Development Program (see Section 4.1, "Government," page 104). The payback was less than two years.

> Regenerative burners have the greatest furnace energy efficiency; up to 85% of the heat in flue gases can be recovered.

Regenerative burners

When a conventional natural gas (or oil) burner is used in the melting furnace, a lot of energy (latent and sensible) is lost up the flue stack. Using the energy in part to preheat the incoming combustion air has been attempted in several ways. One of them is the use of regenerative burners arranged in pairs. They work in cyclic fashion: while one burner fires, the exhaust gases flow through the other where their heat content is stored in a suitable heat-storing material. Next, the firing is reversed. Cold combustion air then passes through this material and becomes preheated, say to 850°C. In tested installations, a 17–20% increase in efficiency followed. The payback was under one year.

Several variations on the regenerative burner technology have been developed. A compact design of Twinbed™ burners and the rapid cycling (about 20 seconds each) of the burners, arranged in pairs, allowed short-term heat storage and reclamation. As a result, the combustion air was preheated to 85–95% of flue gas temperature and the consumption of gas was reduced by 38%. For a northern Ontario foundry, the simple payback (before the price increases of natural gas in 2000) was 5.2 years.

In Japan, in the system developed by Tokyo Gas Co., the heat-storing material (alumina balls) was built into the refractory. Marrying the fuel direct injection (FDI) technology to a full-time regenerative burner produced several benefits:

- The size of the full-time, direct fuel injection regenerative burner (FFR) was reduced by two thirds, as was the piping, resulting in 20% lower capital costs;
- The two streams of fuel and preheated combustion air are introduced into the furnace in parallel. They burn rather slowly, reducing the NO_x levels substantially, far below Japan's regulations. No burner pilot light is used;
- High efficiency of heat transfer from flue gas to combustion air (75%) reduced energy consumed by 40–50%; and
- The payback was two years.

Cupola melting

The 1989 British survey of cupola foundries showed the average specific coke consumption (SCC) of 158 kg/t liquid iron. A U.K. cupola foundry lowered the SCC of their *cold-blast cupolas* to 113 kg/t, a savings of 28%. They achieved this through *improved production planning* to reduce variations in composition, temperature and melted metal demand, *accurate weighing of coke and charge*, and other process improvements.

A U.K. foundry replaced its *cold-blast cupolas* with inherently more energy-efficient *hot-blast cupolas*. The project was also aimed at reducing dust emissions, while increasing melting capacity. The cupola is fitted with four protruding, copper spiral-sheathed water-cooled tuyères (openings in the furnace refractory lining, through which air is forced). Combustion of the flue gas is facilitated by a combination of air addition and an afterburner that automatically ignites if the temperature falls below a preset level. The flue gas preheats the combustion oxygen-enriched air blast to between 490°–500°C. Flue gases are cooled down to about 175°C, after which they are bag-filtered and discharged to atmosphere with only 5 mg/m^3 of particulates, or just one quarter of the maximum allowable content.

In the quest for higher energy efficiency and lowered emissions, coke-fired cupolas may be converted to gas-fired melting. In a retrofit at another U.K. foundry, the cupola was fitted with a water-cooled grate, covered with refractory, which supports a bed of refractory spheres, acting as a heat exchanger. The burners below the grate produce the required reducing atmosphere and lower oxidation losses. The gases preheat and melt the metal, which, as it passes through the bed, is superheated and collected in a well prior to tapping. In the well, a carburizing injector maintains the required carbon level. The payback: 1.8 years.

In still another coke-fired cupola installation, the cupola technology was replaced with an electromagnetic *coreless induction furnace*. The coreless melting furnace is composed of a crucible surrounded by an electric heating coil and refractory insulation. The charge itself acts as a single secondary turn.

The advantage of the coreless induction is that the iron can be melted in batches and, after reaching the desired casting temperature, can be completely emptied from the furnace. No hot residual "heels" need to be maintained, as with channel melting. Another advantage, as opposed to coke-fired or gas-fired furnaces, is that there are practically no emissions; no combustion air is required. That also brings relief in the amount of dust generated as well, and the ease of starting an empty furnace allows a foundry to take advantage of the cheaper electricity rates by melting at night.

A major cupola foundry in Quebec also replaced its cupola furnace with two electromagnetic induction furnaces, with similar results. It doubled its overall energy efficiency to 50% utilization, and increased the productivity as well. Compared to cupola, the induction furnaces saved about 2.5 GJ/t of liquid metal.

Replacing a coke-fired crucible furnace

By replacing its coke-fired furnace with a natural gas/oxygen-heated (oxy-gas) furnace, a Dutch foundry halved the heating and melting time for the copper and copper alloys charge, reduced emissions of pollutants and increased the melting efficiency from 15% to 22%. *(Note: oxy-fuel assisted melting is not suitable for brass because of excessive zinc losses.)* The advantage of using oxygen was in reducing heat losses through elimination of heating the nitrogen portion of air. Significant energy savings were made. The swivelling burner, inserted through the lid of a new drum furnace, was water-cooled.

Electric resistance melting furnace

Because high production runs were not a factor, a small aluminum foundry in Arizona replaced its reverberatory furnaces with electric resistance melting. Stationary furnaces, for melting and holding, and a tilting furnace were installed. Greater production flexibility (+50%), ease of operation, reduced maintenance (–20%) and down time (–10%), and simplified repair were obtained in addition to 28% savings over the use of gas. Scrubbers and baghouses were no longer needed. The payback on energy savings alone was five years.

Induction furnaces

A zinc foundry in Australia replaced its two gas-fired crucible furnaces with one induction furnace. The reasons were increases in gas costs, quality problems due to oxidation products and high maintenance costs (relining of the furnace every 150 melts). Three-phase current was converted to 150 Hz. Improved power factor of 0.80–0.85 was achieved. The switch to induction melting brought these (fairly typical) advantages:

- A 20% reduction in costs;
- Increased production capability due to reducing the crucible relining frequency;
- Increased product quality due to better temperature control that substantially reduced "dross" (oxidation products) from the melt;
- Virtual elimination of local pollution and dust/fumes;
- Lower maintenance;
- Faster melt, which translated into production increase, virtually collapsing the two former shifts into one; and
- No need to stir the molten metal mechanically, as the induction heating does it automatically.

The improved quality, lower labour costs and relining costs, and more accurate temperature control translated into additional savings.

Induction furnace melting for continuous casting

A copper and brass foundry in the Netherlands sought a reduction in energy usage and efficiency improvements. Without modifying either the melting or the casting process, they achieved their objectives by inserting a carefully sized holding furnace in between. From the holding furnace, the molten metal was continuously transferred into the casting machine.

Gas-fired shaft furnace for continuous casting

A British foundry replaced its oil- and gas-fired semi-rotary and tilting melting furnaces with a Striko Etamax gas-fired shaft furnace. The furnace is charged through a vertical shaft in which the escaping flue gases preheat the charge. The furnace has separate melting and holding chambers, heated by recuperative burners. The burners, temperatures and fans are PLC-controlled in dependence on the integrated automatic charging system, which weights the charge. Substantial energy savings (specific energy consumption was 3.93 GJ/t) and other production benefits (reduced melting losses, less labour) resulted in a 10-month payback.

Other EMOs

Housekeeping

- Investigate restructuring of your electricity tariffs with the local utility.
- Investigate the economics of spot purchases of natural gas and /or various gas distributing companies.
- Implement a program of regular inspections and preventive maintenance.
- Maintain proper burner adjustments and monitor flue gas combustibles and oxygen.
- Keep recuperator surfaces clean.
- Schedule production so that each furnace operates near maximum output.
- Minimize the extra delays in the charge-melt-slag-tap-charge cycle.
- Keep the molten metal moving – have the ladle ready ahead of the tap time.
- Maintain insulation of equipment.
- With natural gas-fired furnaces, pay attention to off-gas composition: up to 30% of energy input can be lost in the form of chemical potential energy from the incomplete combustion of hydrocarbons in the furnace shell. Check the gas/air ratio as well as flue gases composition regularly.
- Reduce the furnace (molten metal) temperature if possible.
- Consider consulting with the furnace manufacturer regarding the best way to upgrade the furnace lining to reduce thermal conductive losses.

Low cost

- Drill a sampling port through the furnace lid to limit how frequently the lid must be opened (have it stoppered when not in use).
- Inspect the furnace lid for unsealed gaps between it and the furnace.
- Minimize the time the furnace lid is off.
- Optimize the travel of the charging bucket as well as the ladle as the shortest, quickest way.
- If the metallurgy allows it, sample the molten metal at pouring rather than by opening the furnace lid.
- Control the rate of flue gas exhaust – not by choking the flow on the delivery side of the blower, but by a speed control on the fan motor (consisting of a frequency regulator with a vector modulation). You'll reduce the energy consumption by some 35% and reduce idle power by about 37%.
- Preheat combustion air with the heat from the furnace exhausts.
- Do not superheat the large volume of molten metal in the main melting furnace if your pouring is done in batches. Instead, superheat, if necessary, in a smaller holding furnace just before pouring.
- Consider the application of oxygen trim for even better control of excess air.
- Limit radiation and convection heat losses: add thermal insulation to those system parts that are not insulated or that have insufficient insulation (e.g., burner compartments, ductworks, heat exchangers).
- Upgrade or add monitoring and control equipment.
- Relocate combustion air intake to recover heat from other processes (or from within the building).
- Replace warped or damaged/worn furnace doors and covers.
- Have a spare furnace lid in good repair ready for quick exchange when required.

Retrofit; high cost

- Consider installing a preheater for preheating the charge.
- Consider using oxy-fuel assisted melting in induction furnaces to increase the furnace throughput and reduce electrical power demand (suitable for most metals except brass and zinc).
- Where suitable, consider installation of twin bed heat-reclaimer burners in a retort furnace, which accomplishes heat reclamation through the use of a compact bed of heat-storing material within each burner and rapid cycling of the burners. It is possible to preheat the combustion air to within 85–95% of flue gas temperature and thus achieve 40% natural gas usage reduction.
- If you melt with natural gas, consider using the flue gas to dry and preheat the scrap before charging the furnace.
- Install an air-to-liquid heat exchanger on the furnace exhausts to heat process liquids such as boiler make-up water (large systems may permit the use of a waste-heat boiler).
- Install a scrubber to recover heat while removing undesirable particles and gases.
- For cupolas, consider recuperative system installation.
- Integrate and automate the operational control for optimum energy efficiency.
- Optimize electric arc furnace operations by a continuous analysis of off-gas combustible hydrogen and carbon monoxide, linking that with the regulation of burner ratios, oxygen injections and carbon additions.
- In iron foundries, optimize the use of coke oven gas, blast furnace gas and natural gas to minimize flare-offs and natural gas purchases by optimization of the distribution system capability, automation and computer control.
- Consider using the thermal content of flue gases for preheating the combustion air, and for other uses in the plant.
- For large gas-fired or electric-arc furnace installations, consider installing an *expert furnace system*. This is an optimization process that uses continuous off-gas chemistry analysis as a process control and metallurgy interpretation tool. A few such systems have already been developed in the past few years.
- Upgrade electrical controls of induction furnaces so as to minimize harmonics distortion loss.

2.3.4 Core making

The choice of core-making technology is influenced by the type of metal cast, size and complexity of the casting, desired casting finish quality, type of production equipment, productivity required and the source of available energy. There are advantages and disadvantages to the six most common technologies. From the energy usage point of view, per unit of product (which is the commonly used base for comparison), the core-making process can be ranked, from the highest to the lowest, as follows:

- Oil as the sand binder. The process requires high temperatures for curing, and the cores need to get a refractory coating and paste;
- Green sand, when used for cores, closely follows, with similar requirements;

- Hotbox, also requiring hot curing for binder setting, and usually the refractory coating. It produces solid cores;
- Coldbox requires heated sand and amine gas mixture and no wash;
- Nobakes - depends on air setting of the binder and catalyst and precisely controlled attemperated sand. Usually, refractory coating is necessary; and
- Shell process – coating is not usually required.

TABLE 4:
Relative energy use in core making

Type	Oil	Green	Hotbox	Coldbox	Nobakes	Shell
Relative energy, %	100	85	75	58	38	35

An innovative core making was used by a grey iron foundry in Ontario, which is using removable cores made of interlocking steel components.

Since a foundry must be profitable, any changes to the process must be justified based on the full assessment of variable and fixed costs, capital requirements, adequate payback, etc. A proposal should look into the energy consumption implications as well as the future availability of the chosen energy source.

Other EMOs

Housekeeping

- Switch off the heating equipment (core ovens) when not needed.
- Prevent cold air infiltration into the area (windows and doors).
- Prevent spillage of shell sand.
- Control and analyse core defects/rejects.
- Investigate whether turning off core-making machines using gas or power at the end of the shift is more economical than reheating of the core boxes, and enforce the implementation of the correct approach (or use timers or programmable controls).
- Maintain and calibrate the monitoring and controlling equipment on the core-making machinery and supply streams, and on core drying/baking ovens.

Low cost

- Improve oven insulation.
- Install moisture sensors on water-based wash drying ovens.
- Consider installing automatic programmable controls for the oven (temperature, time, conveyor speed in continuous ovens) and for the control of the fuel consumption by the burners (air ratio, throttling, shut-offs).
- Investigate whether insertion of removable, reusable steel cores would be possible in your foundry (as it is elsewhere) to improve productivity, quality and reduce costs.

Retrofit; high cost

- Consider improving core baking/drying by the application of:
  - Convection drying;
  - Infrared heating;
  - Microwave heating;
  - High-velocity hot air drying to distribute heat quickly and evenly in the oven;
  - Direct firing of the burners into the oven; and
  - Continuous drying.
- Consider the advantages and economics of changing the technology of core making.
- Consider heat recovery on the drying/baking oven exhausts.

2.3.5 Mould making

Mould making may consume as much as 20% of all energy in the foundry, depending on the technology used. The prevalent green sand mould making consists of sand and clay receiving, conveying, preparation, delivery to the mould area, mould handling, shakeout, reclamation, reconditioning and more conveying. This uses all forms of energy in a foundry, and the whole system must be designed in such a way that there are no bottlenecks.

Depending on application, virtually all processes that are used in core making also produce moulds: oil sand, hotbox, shell, nobakes, coldbox and green sand. One process also uses just loose dry sand around the lost foam moulds (see below). Similar principles apply in energy efficiency improvement efforts also in the mould department.

Drying of mould coating

To protect sand moulds and cores from high molten metal temperatures, foundries are using refractory coatings. This reduces scrap, cuts labour costs and improves productivity. The coating is in the form of liquid wash. The carrier liquid can be based on alcohol-chlorinated compound mixtures, which dry quickly without heat, but their toxicity and volatility require emissions controls. Water-based washes are less expensive and are non-toxic, but require a long drying period in gas or electric-resistance heated ovens. The ovens are effective. Nevertheless, application of *infrared heating* for mould coating, developed in joint collaboration by the Electric Power Research Institute (U.S.), can reduce the drying time by as much as 85%. The energy saving stems from the controllability of the infrared unit, which brings the mould surface to the desired temperature and then cycles off in a predetermined time sequence. Less heat is dissipated into the surroundings. The infrared element directs the heat more effectively at the mould and can dry deep cavities and mould pockets – thus contributing to better castings quality. The subsurface of the mould is not affected. An additional advantage was that only 25% of the floor space occupied by the resistance ovens was required. The payback was less than one year.

Lost foam casting

This relatively new technology (currently, just two lost-foam casting plants operate in Canada) offers substantial energy savings (up to 30%). The foam pattern can be of very intricate design. For example, a foundry replaced the need for assembly of 125 pieces with a single foam-cast part. The lost-foam casting can achieve the dimensional precision of high-pressure die-casting. It uses low expansion sand as a moulding medium.

In lost-foam casting, a machined foam pattern is dip-coated or sprayed with a thin ceramic film. After passing of the coated pattern through a dryer, the film now offers protection against molten metal penetration. The pattern is then placed in dry sand (no binders necessary!), which is compacted around it by vibration. Molten metal is poured onto the foam through a sprue. It displaces the foam by melting and subliming it away.

In the monitored installations (by the University of Alabama in 2000), machining and assembly were mostly eliminated for lost-foam parts. Production rates increased several times. Energy consumption decreased also by load reduction from auxiliary equipment. Metal waste was significantly reduced. Moderate pressure application during the solidification phase reduced porosity by an order of magnitude, increased tensile strength by 10%, and showed 100% increases in elongation. The useful life of foam-making machine tools is virtually unlimited, while conventional tools must be replaced after about 200 000 cast parts.

Unique to the lost-foam process is the burning off of the Styrofoam® patterns as the metal is being poured. It produces additional large quantities of recoverable heat in the vented gases; a heat reclaimer can be put to profitable use there.

While the costs of a lost-foam casting machine are about double what a die-casting machine would cost, the several-times-higher output and the advantages described above make the overall economics very attractive.

Other EMOs

Housekeeping

- Do not let equipment run when it is not needed.
- Apply preventive maintenance.
- Ensure regular calibration of the controls.
- Monitor sand composition.
- Control spillage of shell sand (costs).
- Control spillage of sand (eliminate losses and double handling).

Low cost

- Consider installing an automatic sand analyser.
- Install automatic controls for the maintenance of sand temperature.

Retrofit; high cost

- Analyse and optimize the system: look at conveying and handling patterns.
- Automate and synchronize the key elements of the mould-making line.

2.3.6 *Pouring*

Ladles

Since there is ingress of cold air between the ladle and the lid and no heat recovery, the overall energy efficiency for ladle drying and preheating is a mere 10%.

Preheating of ladles consumes a lot of natural gas. We have already mentioned ways to minimize the amount of heat needed to bring them up to the temperature required, as well as methods to cut the heat loss from the ladles by using new types of low-mass, low thermal conductivity ceramic fibre panels or inserts. The ladle heater burners often get inadequate attention; the burner efficiency averaged 53% in iron foundries and was even lower in steel and non-ferrous foundries. With the proper air/gas balance, the combustion efficiency is in the 62–65% range. The appearance of blue flame (i.e., carbon monoxide burning) indicates efficiencies below 58%.

A ladle cover will virtually eliminate radiation losses!

In addition, the *radiation losses* from a ladle holding molten metal are very substantial. Commonly, the foundry may compensate for the radiation heat loss by superheating the metal in the melting or holding furnace, so that when the ladle gets to the pouring station, the metal is at the right temperature. This is, of course, a wasteful practice. The full extent becomes apparent when one realizes the cumulative effect of the many ladle transfers in a year. Other costs may arise due to chills and increased scrap levels. Covering the ladle with a lightweight ceramic-fibre cover during transfers will enable dropping the tap temperatures of the furnace substantially (maybe 50°C), therefore also saving wear and tear on the furnace lining, and improving furnace productivity.

Filters

In non-ferrous foundries, energy and cost savings can be achieved by the use of filters for straining the molten metal prior to casting. Many foundries do not yet filter, perhaps because they are unaware of the likely cost benefits. Inserting a disposable ceramic filter just ahead of the mould can provide a cost-effective way of improving product quality and reducing operating costs. Studies were made in aluminum and copper-based alloy foundries, which proved conclusively significant cost savings for little expenditure – on an average about $800/year per tonne of good castings. Other non-energy related savings were almost as high as well.

The cost of adjusting patterns or dies to accommodate filters is minimal. The benefits of filtering molten metal prior to casting include:

- Higher casting quality (and hence customer satisfaction);
- Reduced scrap and reject rates;
- Higher overall yields; and
- Reduced energy, metal, sand and labour costs.

Use of ultrasound

In an effort to reduce porosity of castings and improve their quality, reduce energy usage and increase yields, a foundry in the U.K. employed ultrasound. The process is cheap and simple to install. To convert electrical energy to acoustic energy, a converter employing the precious metal niobium was chosen. While niobium has excellent corrosion resistance, it absorbs a lot of ultrasonic energy.

Research is being carried out to find a better metal composition for the ultrasound inductor. Nevertheless, the successful pilot application demonstrated the following:

- 95% reduction in traditional de-gassing time;
- Improved metal nucleation upon solidification, leading to a finer grain structure;
- Improved mechanical properties of the castings; and
- Possibility to reduce molten metal temperature by increasing its fluidity.

Energy savings ensued, as did availability of the holding furnaces and increase in the furnace yield.

Robotics may also be used for pouring operations. Installation of the "autoladler" achieves consistency in pouring, is faster and eliminates operator's fatigue and ergonomic problems.

Other EMOs

Housekeeping

- When preheating the ladle, place an insulating blanket on top of it (e.g., using Fiberfrax™ ceramic fibre).
- Analyse the metal transfer and pouring operation with an eye for unnecessary delays, which contribute to the heat loss.

Low cost

- Control process air dew point to minimize re-gassing of metal.
- In permanent mould casting, consider alarming machines for water line restrictions.
- For ladle preheating, consider placing the ladle in a tipped position in front of a wall of refractory material, through which the preheating burner is inserted into the ladle. The small gap between the ladle and the wall, together with the heat reflection from the wall back into the ladle will reduce the burner gas consumption. While this is an Ontario foundry's invention, commercial gas burner ladle preheaters, operating on the same principle using a heat shield-reflector, are available.
- For ladle preheating, consider the economics of using a dip-in, mechanized ladle heater using electricity instead of gas. The preheater modulates the energy input independently of the temperature reached.

Retrofit; high cost

- Optimize the molten metal transfer from the melting or holding furnace to the pouring stations in order to shorten the transfer times, thus minimizing the heat losses and enabling reduction of the tapped metal temperature.
- In batch operations, when superheating of the metal is required, apply it to the smaller quantities in a holding furnace rather than to the larger melting furnace.
- Investigate the possibility of continuous casting (since the process eliminates much of the heating and cooling and saves energy).

- For permanent moulds, rather than "pushing" the metal in, or using gravity fill, consider using vacuum as the medium to draw the molten metal into the mould (it has a positive impact on quality and thus on energy efficiency as well).
- When considering a major upgrade of casting operations for low-pressure permanent moulds and applicable metals, consider automation using a PC-based control system to monitor and control critical factors, such as water cooling, mould temperature, fill pressure and time, etc., for improvements in quality and thus in energy efficiency.
- Similarly, in such situations and for applicable metals, consider application of low pressure, bottom fill casting to improve casting yield and quality, all impacting on energy efficiency.

2.3.7 Sand systems

Commonly, sand is mixed with an oil or chemical binder to make cores, which are then placed into a mould cavity to form the interior surface of the casting. Once the casting is made, the sand cores are removed, and the sand, which contains binder, is frequently mixed with the mould sand. The contaminated sand must be discarded. The disposal issue is very serious, and the CFA has succeeded in helping the foundry industry obtain permission to dispose of the sand in landfills, where it is used as a day cover.

Sand reclamation

As sand reclamation is becoming more common, it puts greater demand on the correct cooling of hot sand. That may be done in rotating coolers, with water used as the cooling medium. The temperature is controlled to within ±2–3°C. The close temperature control is especially critical for the nobake process, or core or mould making. There, too low a temperature delays the binder-setting reaction, and if it is too high it may harden in the box and not strip out.

The customary one-time use of the core sand and its disposal is expensive. A large foundry in Quebec installed a sand reclamation system, which recycles over 90% of the volume of the "contaminated" sand. Binder-contaminated sand is collected in a hopper and augered to a heating bed, from which it enters a fluidized-bed reactor, maintained at 677°C. The heat comes from submerged burner tubes. The clean sand is then cooled down to ambient temperature in a fluidized bed cooling chamber. Cooling is provided by an air-to-water exchanger. The foundry claims that the thermally reclaimed sand has better characteristics than new sand. Up to 100% of the reclaimed sand can be reused. According to the 1999 news release, the recycling of 1 t of sand used 31 m^3 natural gas and 28 kWh of electricity; total savings were about 90% and the payback was just under two years.

A similar system for thermal reclamation of furan-binder based, nobake mould and core sand was installed by an Ontario foundry, which can recycle up to 98% of the sand.

Improving process controls in the mullers helps produce well-mixed, uniform, good-quality moulding sand. This, in turn, will generate fewer broken moulds, sand holes and casting repairs, and less burned-on sand and scrap, all of which needlessly consume additional energy.

Other EMOs

Housekeeping

- Limit your sand disposal expense – rather than using costly landfill, negotiate disposal through your local asphalt-making company.
- Switch off the sand system equipment when not in use.
- Power-up and power-down the sand system equipment in production sequence, not all at once, when parts of it are not yet (or no longer) needed.
- Pay proper attention to the classification of the reclaimed sand in order to maintain mould and core quality.

Low cost

- To reduce sand mould defects and improve sand consistency and uniformity, consider using an automatic sand tester at the mullers to test for compactibility, strength and moisture, and to govern the muller operation and sand composition (e.g., Hartley™).

Retrofit; high cost

- Consider installation of a thermal reclamation system (e.g., Thermfire™ type using turbulent flow precipitators); only about 2% of make-up sand is required after the reclamation.
- Mullers use some of the largest and hardest-working electric motors in the foundry. In large foundries, consider staging of mullers' production – use one for steady, continuous production and the other to cover the peak demand periods. Alter them to ensure their even wear and tear.
- Consider replacing the energy and maintenance intensive pneumatic conveying of sand with belt or bucket conveyors.

2.3.8 Cleaning and finishing

Whatever methods are used for cleaning of the castings, such as shot-blast in abrasive cleaning, grinding wheels, electric-arc cutoff torches, etc., they should be examined for energy-saving opportunities in general, based on proper operating practices and equipment maintenance.

Electrohydraulic cleaning

The shakeout is a major source of dust in a foundry and is a very energy (or labour) intensive operation. The use of electrohydraulic cleaning addresses these two aspects in an imaginative way. The castings are immersed in a water tank, and a high-voltage discharge between the casting and the submerged electrode produces a shock wave. The shock wave strips the sand from the casting. The cleaning is done in seconds and uses very little energy. No dust collection system is required which, in turn, reduces the amount of ventilation make-up air. In addition, the hot castings warm the water. After treatment, the heat from the water can be used elsewhere in the foundry. In addition, the need for shot-blast operations may be reduced or even eliminated. On the other hand, of course, water management and wet sand reclamation must be adequately addressed.

Mechanical grit blasting

Cleaning of castings down to the bare metal surface, suitable for further treatment, is normally done by grit blasting using compressed air. To accelerate the grit by compressed air is energy inefficient and expensive due to the high cost of compressed air. A foundry in the Netherlands uses the grit-blasting method, where the grit is accelerated by mechanical paddle wheels instead of compressed air. The energy is therefore used more efficiently. Energy savings on cleaning of 120 000 m^2 of cast surface amounted to 1 000 000 kWh/y and 120 000 m^3/y of natural gas. The payback was 2.1 years.

Housekeeping

- Apply preventive maintenance to the casting cleaning equipment and tools.

Low cost

- For cutting work, consider switching from electric arc-air torch to gas-oxygen torch.
- For cutting work, consider switching from high-pressure MAPP gas to low-pressure bulk natural gas, supplemented with oxygen.
- Consider using trimming dies for high production runs of non-ferrous castings.
- Consider using hydraulic wedges for breaking off the risers and runners.

Retrofit; high cost

- Instead of sand or grit blasting for cleaning permanent moulds, consider using "dry ice" pellets of solid carbon dioxide (CO_2); the technique also works well for general preparation of surfaces for painting. Obviously, only the blasted-off impurities need to be dealt with, not the sand or shot.

2.3.9 Heat treating

In heat treatment (such as heating, stress relieving, tempering, high-temperature annealing), major energy losses come from:

- Heat losses through the outer shell of the heat treatment furnace due to inadequate refractory lining;
- Poor burner performance (type, fuel/air adjustment);
- Negative pressure in the furnace/oven;
- Air infiltration; and
- Inadequate heat recuperation from flue gases.

Furnace lining

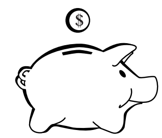
Increasingly, replacement of firebrick with ceramic pyrobloc modules is gaining favour for their excellent insulating properties, low heat storage and low heat loss, fast thermal cycling and reduced maintenance requirements. Thick firebrick lining wastes energy due to its large mass and the ability to develop cracks. To illustrate the low thermal transmission of these materials, the outer shell temperatures of 260–320°C with firebrick lining can be reduced to 40°C with the modular ceramic insulation lining. The ceramic fibre properties may eliminate the need to keep the idle furnace on low fire. This eliminates extra fuel consumption because the ceramic fibre-lined furnace can be rapidly restarted and brought up to temperature. As well, ceramic fibre-lined furnaces have lower maintenance requirements and muffle sound; their operation is quieter.

Burner performance

The burner fuel efficiency can be improved in many ways, some of which have already been described in Section 2.3.3, "Melting" (page 51) and in a few examples of different approaches shown below.

Air infiltration

The infiltration of outside air is a major problem. It has to do both with maintaining the positive pressure in the furnace and with keeping the insulation and seals around the furnace door in good repair. Normal wear and tear on the furnace will cause gaps in seals around doors and cracks and crevices to appear, which will contribute to major energy loss. Preventing cold air ingress will maintain the desired furnace atmosphere, improve temperature uniformity by avoiding chilling of parts of the load, and save fuel by not having to heat infiltrated air.



> The benefits of furnace or oven pressure control lie in ongoing future savings.

Even a correctly designed furnace can develop negative pressure. This is because the flue openings and chimney dimensions are designed to maintain correct pressure under full load conditions. On small loads, with lower heating requirements, the furnace will have negative pressures.

One way around this is to control the opening of the damper in the flue by a pressure transmitter located on the side of the furnace near its hearth. The flue damper is controlled by a modulating control and butterfly valve which, in turn, is controlled by a pressure controller in the furnace control panel. Keeping positive pressure will prevent cold air infiltration as well as ensure that the furnace operates as efficiently as possible.

> Infiltration: Air heated for no useful purpose at an approximate cost of $25,000/year!

To illustrate the extent of air infiltration: Take a furnace with a 4.9 m × 3.7 m (16 ft. × 12 ft.) door and a gap of a mere 3.8 mm (0.15 in.) wide, with a furnace draft of –8 Pa/m (–0.01" WC/ft) and negative furnace pressure of –30 Pa (–0.12" WC). The rate of infiltration through the combined opening of 1250 cm^2 (i.e., 1 m × 12.5 cm or 200 sq. in.) is 2400 m^3 (85 000 cu. ft.) air per hour!

Controlled atmospheres

Controlled atmospheres, designed to offset the decarburizing effect of oxygen, are expensive to maintain. The generation of endothermic or exothermic protective atmospheres consumes a lot of natural gas or propane. A few examples are mentioned below. The alternative is to purchase bulk liquid nitrogen gas. In a small foundry that cannot afford its own generators, the expensive purchases of nitrogen gas must be carefully managed and its use reduced through conservation measures.

An alternative for newly planned treatment facilities may be the consideration of *vacuum heat treatment* processes.

Heat treatment examples

Pulse firing

A foundry in Quebec heat treats parts up to 1000°C and holds them at this temperature for several hours. In a major retrofit of the annealing furnace, it employed a pulse-firing system, ceramic fibres, furnace pressurization and micro-processors to regulate the burners. Each burner is fired at a predetermined frequency and order at only one selected rating. The result is a high turbulence inside the furnace (i.e., high convective heat transfer to the parts) and minimal temperature variation between zones (as low as 4°C). The gas consumption dropped to 31% (!) of the original levels, and the retrofit investment costs were paid back in 10 months. The annealing furnace works reliably and contributes to increasing efficiency, productivity and product quality.

Continuous quenching/tempering

A major metal-casting concern in Japan installed a continuous quenching/tempering process to treat metal parts in an oxygen-free, inert atmosphere. The process requires nitrogen gas generation. The exothermic reaction normally took place externally to the furnace and the heat was wasted. After the retrofit, the inner atmosphere generation was taking place inside a special radiation tube inside the furnace. The heat is captured and utilized in heating the metal parts. The inert atmospheric gas is generated by burning a gas/air mixture in a precisely controlled ratio. The flue gas is purified, reheated in a flue gas exchanger and reintroduced to the furnace, with 0% content of O_2. Furthermore, the heat from the exhaust gas of the furnace is recuperated for product preheating. In addition, the heat from the quenching oil is recovered to warm the washing fluid used in the intermediate cleaning unit. The energy consumption was cut by 55%. The payback was less than one year.

Annealing with a fuel-based nitrogen generator

A foundry in Ohio implemented a fuel-based nitrogen generator (FBNG), with a twist. It produces the inert atmosphere required for both ferrous and non-ferrous annealing applications by halving the total energy required normally to produce and separate nitrogen by compression. In addition, it generates steam that can be used in other plant applications. The process received a Special Recognition Award from the U.S. Department of Energy.

In the FBNG process, natural gas and air are combusted. The combustion gases are cooled to remove most of the moisture. The gas is then compressed and passed through a catalytic converter, which removes any traces of oxygen. In addition, the NO_x gases are reduced at that stage by 95%. A second converter removes residual water and CO to produce CO_2, which is subsequently removed by a molecular sieve. The resulting atmosphere meets the required quality criteria.

By helping to achieve excellent surface quality, it could eliminate a post-anneal acid cleaning step.

A broad range of atmosphere compositions can be produced to meet the needs of a particular process; hydrogen content range is 0–15%, while oxygen is only 5 ppm and combined CO and CO_2 will not exceed 0.15%. Conventional systems contain usually upwards of 10 000 ppm (i.e., 1%) O_2. The chief benefit of the FBNG technology is its low fixed operating costs. The payback period was 1.6 years.

Other EMOs

Housekeeping

- Maintain the tightness of seals and insulation around the furnace door.
- Maintain the calibration of monitoring and control instruments.
- Maintain the proper adjustment of the burner controls.
- Check the oxygen content in the furnace/oven and flue gases regularly.
- Consult with your furnace/burner manufacturer on the best operating conditions.
- Check the tightness of flue attachments to ovens to prevent the release of carbon monoxide into the foundry atmosphere (and hence the unnecessarily increased ventilation rates).
- In controlled atmosphere operations, operate furnaces with minimal flow of the protective atmosphere. This is necessary from the cost point of view (less atmospheric gas needs to be generated) and because of heat losses.

Low cost

- Consider an upgrade with high-efficiency burners.
- Consider the use of regenerating burners in the heat-treating furnaces.
- Consider repositioning of the burners to achieve higher turbulence inside the furnace for improved heat transfer and uniformity of heat treatment.
- Add insulation to the outer surface of the furnace.
- Consider improving the door seal by using ceramic fibre and stainless steel mesh in a channel arrangement, for a flexible seal.
- Install automatic regulation of the furnace pressure through damper control.
- Change the method of conveying product through the treating oven to facilitate rapid heat transfer to the product (e.g., exchanging wagons for open heat-resistant racks/platforms, etc.).
- Preheat the combustion air, using any of the convenient waste heat sources in the foundry.

Retrofit; high cost

- Consider retrofit or replacement of the heat-treating furnace if it is run:
  - On three shifts;
  - Kept at temperature over the weekend with no production going on;
  - With no excess air control; and/or
  - With firebrick lining and excessively high outside shell temperatures.

- Consider replacing firebrick in heat-treating furnaces with pyrobloc modular ceramic insulation, which allows faster heat-up/cool-down and fuel efficiency.
- If production requirements have been reduced, consider re-sizing/partitioning the furnace.
- In a continuous heat-treating operation, consider using the hot gas from the exit vestibule and piping it to the entry vestibule to preheat the charge.
- In batch furnaces, extract the heat from the exhaust atmosphere by suitable heat exchanger (e.g., heat wheel, ceramic regenerators) to preheat the incoming atmosphere gas.
- On continuous treating furnaces using endothermic gas, consider using the exiting endothermic gas (with about one fifth of the natural gas heating value) in radiant-tube burners for preheating the parts.
- Consider reclaiming heat from the steam generated by quenching operations.

2.3.10 Special processes

Thermal galvanization

For thermal galvanization, iron parts must be cleaned of grease, dirt, rust and mill skins. They must be first degreased and passed through a mordant bath, a flux bath and a drier. The mordant bath usually becomes polluted by iron particles that migrate into the zinc bath. There, crystals of iron/zinc settle on the product and on the bottom of the bath. Quality of the product is impaired and frequent cleaning of the zinc bath is required. This results in losses of zinc, and of productivity. A galvanizing foundry in the Netherlands installed equipment for regeneration of the flux bath. In a reactor, chemicals are added to the fluxing fluid to react with iron and convert it to iron hydroxide, which is filtered out. The clean fluids are returned to the bath. In addition, the on-site generation of chlorine for the iron oxidation was replaced by the use of hydrogen peroxide, H_2O_2, which further saved electricity. The payback was two years.

Electroless[3] nickel-plating

A U.S. corporation developed a nickel-plating chemical plating process that does not require electrical current. It uses a regenerative process technology, based on a multi-compartment electrochemical cell, to control the pH of the plating bath electrodialytically. Selectively, useful anions are returned to the bath. The new process also eliminated the expense of treating and disposal of the spent bath waste.

2.3.11 Waste heat recovery

A casual look will show many sources of waste heat: in melting furnace exhaust, ladle preheating, core baking, pouring, shot-blasting, castings cooling, heat-treating, quenching, ventilation exhaust, etc. To use waste heat profitably at a desired temperature level, its temperature must be raised by suitable equipment.

[3] Electroless plating is the deposition of metal coating by immersion of metal or non-metal in a suitable bath containing a chemical reducing agent. (*McGraw-Hill Dictionary of Science and Technical Terms, second edition*, 1978).

Many opportunities for heat recovery in the foundry industry are not yet utilized. It is a complex subject, best handled with the help of a competent consultant. The current volatility of our economic situation, particularly with respect to rising energy prices, should make this an interesting subject to explore. The steps to take are:

- Perform a heat balance: compare (quantify) the heat demand and potential waste heat supply;
- Assess how easy it is to access the waste heat, and the distance involved in bringing it to the point of use;
- Assess the type, heat content and condition of waste heat sources;
- Determine the degree of heat upgrade required;
- Short-list equipment/process options; and
- Perform economic evaluations to select the optimum solution.

> Waste heat is the rejected heat released from a process at a temperature higher than the temperature of the foundry air.

The principal parts in a heat recovery system are:

- Waste heat source (e.g., exhaust hoods, furnace ducts, hot water from furnace cooling);
- Heat exchanger (in case of high exhaust temperatures, a waste heat boiler could be employed; note: a feedwater system would be required);
- Heat distribution system; and
- Heat recipient (e.g., in case of a waste heat boiler employment, a steam turbine with generator (or air compressor) and condenser, ventilation air, combustion air, raw material drying oven preheater, etc.).

> The best solutions involve the **heat cascading principle**, where waste heat is utilized several times on subsequent lower levels.

A wide range of equipment for heat reclamation is available. The waste heat sources with the highest temperatures are the off-gases from melting and heat-treating furnaces. Waste heat from treating furnaces is the cleanest, steady temperature source with no particulates or corrosives. Other high-temperature waste heat sources include pouring and core baking, but the intermittent nature of waste heat generation or the relatively small streams make economic utilization difficult.

Additional sources of waste heat in a foundry include:

- Furnace dust collectors;
- Reverberatory furnaces;
- Cooling water;
- Sand-cooling drums;
- Burning off mould patterns (see "Lost foam casting," page 65);
- Induction furnace preheaters;
- Copper-melting furnace;
- Process water; and
- Cupola start-ups and shutdowns.

The possibilities for waste heat utilization include the following:

Preheating combustion air
We have already demonstrated the profitability of preheating combustion air. Even after preheating the combustion air, there may be enough residual thermal energy to be used economically for another application, e.g., to provide building heat or low-temperature process heat. The extraction of heat from the furnace flue gases is usually done in a *recuperator*. The many types available on the market use a variation of the three basic types: counter flow, parallel flow or cross flow. About 65% of the waste heat can be recouped.

Preheating of process gases
This may be applicable to heat treatment furnaces using protective atmospheres, as well as to the furnace itself, for preheating the fuel gas, with corresponding (and quite substantial) natural gas savings. Gas-to-gas heat exchangers of many configurations are used for this purpose.

Preheating raw materials and parts
For raw materials entering the process with possible water and oil contamination, preheating helps in driving the moisture and oils away and increases the temperature of the material for melting, thus saving energy required for melting.

Similarly, the thermal load required for heat treatment of parts is lessened by their preheating.

Any hot fluid in a foundry can be used as a heat source through the utilization of liquid-to-liquid or liquid-to-air heat exchangers.

A water-to-air heat exchanger is 100 times more effective than an air-to-air exchanger.

Consider investigating the use of water jacket heat exchangers from sources such as electric arc furnaces or cupolas. The reclaimed heat could provide domestic hot water and water coil-based space heating. Additionally, in cupolas, water-based heat reclamation would reduce the need for evaporative cooling and scrubbing of the gases, leading to other substantial energy savings.

The literature is rich with successful case histories of imaginative and innovative waste heat utilization, ranging from domestic to aquaculture applications.

Some of the uses include:

- Space heating;
- Supplementing drying of refractory wash coatings;
- Ventilation make-up heating;
- Water heating;
- Process cooling; and
- Absorption cooling for air conditioning.

Other EMOs

Housekeeping

- Determine and eliminate as many waste heat sources as possible.
- Reduce the waste heat temperature.
- Perform regular and preventive maintenance of the foundry systems.
- Maintain the calibration program for monitoring and measuring instruments.

Low cost

- Consider returning the recovered heat to the operation from which it came, as a priority, since such systems usually require less control and are less expensive to install.
- Improve operational controls.
- Re-use hot exhaust air for preheating/drying of raw materials.
- If air compressors are water cooled, look for ways to recover heat from the cooling water and/or for recycling the water for use elsewhere (Note: many companies reported successful and profitable heat reclamation from, e.g., screw compressors).
- Use the reclaimed heat from air compressors for preheating of ventilation make-up air.
- Use the captured heat from melting furnaces to preheat incoming ventilation air (or combustion air, if natural-gas fired).
- Use the heat from the heat exchanger for the furnace cooling to heat the foundry buildings (locate the exchanger inside).
- Use the waste heat from filtered, clean air leaving dust collectors as heated make-up air. Make sure you have adequate controls in place to ensure the integrity of the filters/baghouse and that there are no toxic components in the air.
- If you have a high-quality waste heat source (i.e., with a high temperature differential), yet the potential place for its utilization is at some distance, consider transferring the heat to a liquid, which could be pumped to the destination easily.
- Consider storing waste heat (via liquid or eutectic salts) if there is a delay in its application.
- Consider using waste heat to drive air-conditioning units.

Retrofit; high cost

- Consider investigating the newly developed hybrid (absorption/compression) heat pump (by the Institute for Energy Technology of Norway) for upgrading waste heat from 50°C to a temperature of 100°–115°C. The heat pump can both produce heat well in excess of 100°C, as well as supply cooling, typically for air-conditioning applications. This is an important consideration for foundry ventilation systems.
- To recover energy from a high-temperature flue gas containing dust and particles (e.g., from a cupola furnace), consider using a waste gas tube boiler or water tube boiler for waste heat recovery, newly developed by the Norwegian Association of Energy Users and Suppliers (KNE).
- In galvanizing foundries, consider reclaiming waste heat from zinc bath flue gas by preheating the flux mordant and degreaser baths as well as the dryer.
- In galvanizing foundries, investigate fitting the pre-treatment reducing-atmosphere furnace (with its preheating, glowing and cooling sections) with gas burners with integrated heat recovery units. The radiation elements are equipped with heat exchangers in which the combustion air is preheated by the element's own exhaust gases.

- Consider replacing cooling towers with a heat transformer that upgrades the temperature of waste heat to the required level, to produce saturated steam. In the next stage, an existing boiler may superheat the steam to prevent condensation in the distribution system, and augment steam supply (e.g., equipment by Finish manufacturer Rinheat-Ahlstrom).
- Consider converting high-temperature flue gas heat from melting and holding furnaces into superheated steam for steam turbine power generation.

Additional information: Apart from a number of current monographs, a comprehensive technical manual, *Waste Heat Recovery* (M91-6/20E) is still available from NRCan at (613) 947-6814. It provides a good overview of the subject. Other monographs in the Energy Management series are listed in Appendix 5.7.

2.4 Foundry buildings

The impact of foundry buildings on overall energy use should have been evaluated during the initial energy audit and made an integral part of the foundry's energy management program. We may find that older buildings are often inadequately insulated and sealed.

Modern building codes set minimum requirements for energy conservation in new buildings, which *apply in full also to repair, renovations or extensions of older buildings*. Energy efficiency shall be designed to good engineering practice such as described in, for example, *Model National Energy Code for Buildings 1997 or Ontario Building Code 1997* ("code") and in ASHRAE/IES 90.1-1999 – "Energy efficient design of new buildings." When considering energy efficiency improvements, these and many other regulations and standards that cover industrial buildings' construction and operations (such as insulation, heating and ventilation) must be carefully examined to ensure that health, safety and occupational comfort requirements are met.

Here, we shall mention only items relevant to the integrity of the building envelope – *heat transfer and moisture protection*. Other related issues, such as heating and ventilation, are covered separately.

There are three major ways to control two-way heat transfer (loss or gain) through the building envelope:

- Reduce it through adequate insulation of walls, roof, windows and doors;
- Reduce it through proper weatherproofing, which prevents water infiltration; and
- Reduce uncontrolled air movement through the envelope's normal openings and seal deficiencies.

Upgrading of *wall insulation* from the inside may not be practicable in older buildings. The solution may be to add insulation to the exterior of the building and cover it with new weatherproof cladding.

Roof insulation upgrades may be desirable because most of the winter heat loss and summer heat gain occurs through the roof. A new insulated roof membrane can be covered with heat-reflecting silver-coloured polymeric paint to help minimize the heat transmission.

Many older foundries have single-glazed, inadequately sealed *windows*. Short of replacing them with modern sealed-glass windows, plastic or glass-fibre window panels can be used to advantage. Some panels are manufactured as double-glazed unbreakable units that are more energy efficient than single-glazed glass windows. Double-glazing is the minimum standard for Ontario. Other solutions include:

- Choose improved sealed units for north-facing and highly exposed windows;
- Standard triple glazing; it adds an extra air space (and also weight) and thus insulation;
- Glass coatings reduce heat emissivity and reflection;
- Low-emissivity (Low-E) coating reduces radiant heat through the glass and achieves about the same insulation as uncoated triple glazing;

- Gas fill – commercially available units with the inter-panes space filled with argon or krypton increases the insulation still further; and
- High-performance triple glazing – it may utilize Low-E as well as gas fill. The insulating value is almost five times as great as that of a single-glazed window.

Windows can also be shaded or curtained inside or shuttered outside to keep out summer heat and winter chill. Sometimes a single-glazed window wall causes large heat losses/gains. Consideration may be given to covering it – to the degree desired – with insulated wall panels.

A foundry may have *external heating cables* installed to prevent the formation of ice, for example in gutters and downpipes, on flat roofs with internal heated downpipes, on driveways, and in entranceways. Often the power stays on all winter long. Manual control, often crude and imprecise, may be causing energy consumption to be higher than necessary. An effective solution may be to integrate the controls of this and other energy systems in the central building energy management system.

Other EMOs

Housekeeping

- Maintain the integrity of water-impervious roof membranes through regular inspection and maintenance.
- Door seals at loading docks should be inspected regularly; worn or damaged seals leave large gaps between the dock and the trailer and should be fixed promptly.
- Examine all openings (vents, windows and outside doors) for cracks that allow air to leak in and out of the building.
- Block the cracks with caulking or weatherstripping.
- Keep doors closed; they lose the most heat when open.

Low cost

- Vestibules, revolving doors and automatic door closers all help reduce losses from open doors.
- Close off all unused openings and stacks.
- Caulk and stop all cracks in the building walls, etc.
- Upgrade weatherstripping of windows and doors.
- Eliminate unnecessary windows and glass walls.

Retrofit; high cost

- Weatherproof exterior walls with cladding or another treatment that prevents water infiltration.
- Install adequate, leak-proof vapour barriers on the interior (warm) side of walls, ceilings or floors.
- Consider investing in a central building energy management system.

2.4.1 Heating

The paradoxical situation when, in winter, the foundry building's heating is operating at maximum, while the loading door or scrap bay 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 foundry's operating costs. Typically, a foundry has a lot of waste heat available, which could be used for space heating. The challenge is in how to use it intelligently to create a comfortable, fumeless working environment.

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

Buildings with large south- or southwest-facing walls can be retrofitted with a type of solar wall (e.g., Canadian-developed SOLARWALL®) for even greater energy efficiency in space heating.

Other EMOs

Housekeeping

Changes to employee behaviour toward energy management can lead to a virtually costless achievement of substantial savings:

- 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).
- Adjust maintenance work in the paint line to shorten maintenance periods.
- Assign someone (e.g., maintenance) to switch off machinery at the end of the workweek.
- Switch off lights and air conditioning when leaving an office.
- 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.
- 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 foundry building temperature).
- Repair broken windows, skylights and doors.
- Ensure that heating and air-conditioning systems operate only when required.
- When no production is going on, and on weekends, reduce as much as possible the amount of fresh air brought into the plant.
- Turn off air-conditioning units in the cafeteria and in the offices on weekends.

Low cost

- After the hot air from core making machines has passed through dust collectors, recirculate it back into the building for heating purposes (in winter).
- Locate the heat exchanger for the furnace cooling inside the foundry building: it will help heat it in the winter. An additional benefit: worries about freeze-up or charging the system with antifreeze are minimized.
- Use radiant heating directed at work stations rather than general space heating.
- 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.
- Plant trees or shrubs outside as windbreaks and summer shade.
- 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 winter, to mix with and temper the outside air to provide heat to areas below.

Retrofit; high cost

- Innovative use of passive or active solar heating technology for space and/or water heating, especially when combined with improved insulation, window design and heat recovery from vented air.
- Installation of a solar wall (e.g., SOLARWALL®, Trombe wall) on south or southwest side to provide effective heating.
- Consider using evaporative cooling of flat roofs to reduce air-conditioning loads in summer.
- Consider utilizing heat pumps (or ground heat pumps) for combined heating and cooling of the foundry facilities.

2.4.2 Air management

Commonly, foundries 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 dusty atmosphere and sometimes high carbon monoxide (CO) content. For this reason, the construction of foundries traditionally allowed for ample sizing of roof monitors and exhaust stacks. That was often done with little thought on the proper location of these vents or on the distribution of air make-up.

Excessive air exhaust results in high under-pressure in the building and draught problems. In production areas inside foundries, the existence of too many exhaust 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 winter. To add to the waste, city water may be sewered after providing just once-through cooling.

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

A foundry dealt with dusty and hot exhalants and its ventilation needs in a combined way: flue gases were passed through scrubber/heat exchanger, and the incoming air was preheated in the 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 polluted areas of the plant, with separate fans for each of the zones. The exhaust fans also had speed regulators. The whole system, connected to a central monitoring system and controlled by a PC, obtained a balance between the inlet and outlet sections of the total ventilation system. The energy costs for the plant ventilation were halved as the result and the incoming air was no longer polluted with the dusty exhalants as before.

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

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

Other EMOs

Housekeeping

Unnecessary exhaust of 10 000 cfm translates to about $1,500/yr. in heating costs!

- 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 make-up air when not required.
- Assign someone (e.g., maintenance) to turn off the fans, close the vents, etc., at the end of the week. Prepare a checklist so that nothing is overlooked.
- Conversely, put someone in charge to switch on the ventilation system 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.
- Clean or change dirty air filters regularly.
- Examine your present system – perhaps the original dust collection/exhaust system was designed to handle larger volumes of air than necessary for ordinary plant operations. Maybe some of the fans could be taken off-line, at zero cost, for immediate benefits of:
  - Reduced maintenance;
  - Lower energy costs;
  - Reduced emissions; and
  - Reduced noise.

  You can easily verify this by turning the selected fans off and watching what happens.
- Pay attention to the upkeep of your baghouse/dust collection system; monitor both its integrity and resistance (i.e., proper functioning) by a differential pressure gauge (e.g., water column gauge).

- Monitor CO (carbon monoxide) levels at head level around pouring and shakeout, and corners away from these areas. It will give an additional indication of the ventilation effectiveness.
- Keep the motors on forklift trucks and other foundry vehicles well tuned, to reduce the excessive release of CO into the foundry atmosphere, which increases ventilation demand.
- Watch for "shortcutting" of heated make-up air directly to a nearby exhaust fan.
- Check the temperatures of indoor air high up in the foundry roof area for potential to recapture the heat from relatively clean areas.
- Delay the start of foundry ventilation at the beginning of operation until the heat of melting, pouring, shakeout, etc., has warmed the air inside.
- Where required, cut small openings into large doors to allow the passage of forklift trucks; use transparent curtains to prevent continuous blasts of cold air from outside.

Low cost

- Install strategically located hoods over dusty/hot areas. Make sure that they have ample dimensions so that the heat or dust does not escape into the general space.
- Tie the exhaust fans from dusty areas, e.g., the mould shakeout, to the activity: have it on only during the dust generation period (which is usually intermittent); throttle the fans down during idle periods. Another examples of this application of modulated ventilation is in blast rooms or oxy-gas burn-off stations, during charging of an induction furnace, floor mould pouring and cooling, etc.
- Recapture the heat that accumulates high up in the foundry rafters – push it down in the winter (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 (e.g., for air classifiers for wheelabrators; shot-blast rooms).
- Install high-velocity air curtains at loading bays and other large openings.
- Consider installing double-door vestibules or windbreaks in northwest locations of the openings.

Retrofit; high cost

- Replace the general ventilation of the entire area with locally situated, hooded exhausts from areas that need to be ventilated (e.g., over bake-core making machines, furnaces, ladles and pouring stations, especially in non-ferrous foundries).
- Fresh air of constant temperature can be provided in a foundry by the installation of a new ventilation system using a rotary heat exchanger. The warm exhaust air heats the incoming air in the exchanger. The temperature is controlled by the number of revolutions of the exchanger (payback in an iron foundry is about two years).

2.4.3 Insulation

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., melting furnace) reduces the amount of fuel needed to produce the heat – and thus the emissions. The reduction may take place locally or, in the case of electricity, upstream at the generating station.

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

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

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

Thermal insulation deteriorates over time. A re-evaluation of long-established systems may show that the insulation is inadequate or damaged. For larger foundries, an investment in an infrared thermograph (video camera) may pay for itself in a short time. Alternatively, 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 foundries, fuel prices have skyrocketed.

> Base the choice of insulation material on:
>
> - Halocarbon-free
> - Flammability/resilience
> - Performance/price

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 types, causes the displacement of insulating air by moisture/water ingress (e.g., leaking steam or condensate pipes). Effective cladding of the insulation is just as important as selecting the most effective type of insulation and installing an economic thickness. Waterproofing is therefore an integral part of any insulating job. For high-temperature applications, chose a vapour-permeable covering that will allow moisture to pass outward.

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

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

Other EMOs

Housekeeping

- Review economic thickness requirements; consider long-range energy costs.
- Check condition of insulation and covers/cladding periodically.
- Repair damaged insulation, coverings and finishes as soon as possible.
- Replace wet insulation; it has very little insulating value.
- Locate source of moisture; in particular, establish whether a pipe or piece of equipment is leaking.

- Maintain safety requirements for hot surfaces.
- Repair seals around furnace openings, lids, etc.
- Minimize access to the furnace through doors, ports or covers to an absolute minimum to lessen radiation heat loss.
- Cover the exposed metal surface furnace spouts during non-production periods with graphite or a ceramic fibre lid.

Low cost

- Fit long exposed lauders with removable ceramic fibre lids.
- Insulate non-insulated pipe and ductwork.
- Insulate not-yet-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 zinc baths in galvanizing foundries.
- Cover the zinc baths during the night.

Retrofit; high cost

- Replace refractory firebrick with ceramic pyrobloc insulation on ladles, lauders and furnaces.
- Add insulation/exterior cladding to foundry buildings, roofs, crawl spaces, etc.

2.4.4 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. The evaluation of lighting systems is mandated by the *1996 Energy Efficiency Act*, which sets minimum requirements for lamp efficacy and lighting quality. The energy audit of your foundry should help in determining conformance to the regulations. Electric utilities, manufacturers of lighting products and consultants can also provide help.

Bulb efficiency %:

Incandescent = 100

Fluorescent = 300

Metal halides = 400–600

High-pressure sodium = 450–700

Our drive to increase lighting energy efficiency should not diminish the requirements of adequate lighting of the workplaces. A 2000 report on the survey of Canadian foundries compared the range of existing lighting levels with the requirements set by the Illuminating Engineering Society of North America. There were sharp differences in lighting levels, increasing with worker's age.

TABLE 5:
Lighting levels (in lumens/sq. ft.) throughout foundries

Area	Typical level range (average)	Required for workers aged under 40	40–55	over 55
Moulding	3–300 (41)	100	150	200
Pouring	6–450 (63)	50	75	100
Core making	5–300 (49)	75	100	150
Grinding	4–180 (56)	100	150	200
Inspection	2–117 (49)	100	150	200

After L.V. Whiting; Note: 1 foot-candle = 1 lumen/sq. ft.

It is worthwhile to consider this table 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 reduces absenteeism;
- Positively influences quality (i.e., better workmanship and improved customer satisfaction);
- Allows for better control of costs by reducing defects and rejects;
- 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); and
- Positively influences the company's image and personnel's self-image.

In reducing lighting costs, focus therefore on improvements to housekeeping and the energy efficiency of lighting fixtures rather than on reducing the lighting intensity in workplaces.

Pay attention to selecting the right type of lighting fixture for the environment. Position the fixture to minimize light loss from dust accumulation (fluorescents are the worst in this respect), and position it so that there are no obstructions to lighting.

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

Other EMOs

Housekeeping

- Assign responsibility for turning off lights at the end of the production day, and turning them on prior to the start of shift in each department and in general areas.
- Establish a regular cleaning schedule for lamps and shields of light fixtures – particularly in dusty environments.

Tip

Lamps get dimmer with age yet continue to use the same power: re-lamp!

- 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 lot is not in use.

Low cost

- Use motion detector light switches where feasible, e.g., offices, storerooms, etc.
- Consider using motion detector light switches or photocells for outside floodlight control.
- 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.
- Where the environment permits, paint the walls and ceilings with lighter colours and use the light reflection to improve the brightness of the workplace.

Retrofit; high cost

- Replace lower-efficiency lighting with more efficient types (e.g., mercury lamps with high-pressure sodium lamps).

3.0

Putting it all Together: Closing the Gaps

3.1 Identifying energy management opportunities (EMOs)

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

- Results of the initial energy audit;
- Results of energy and material balances;
- Review of literature, including Internet sources;
- Information about applicable ideas from other foundries and other industries;
- Consultations with NRCan's CANMET and Office of Energy Efficiency;
- Equipment supplier recommendations;
- Consultants' advice; and
- A fresh look at the way the foundry manages its production and operations.

It all could result in a very long list of energy management opportunities (EMOs). The EMOs fall into these broad categories:

1. **Organizational changes** – the changes in planning and scheduling production in a way that allow for a partial or across-the-board levelling of energy use, hence its better utilization;
2. **Process changes** – improvements in process equipment and technological changes that result in reduced energy consumption;
3. **Energy efficiency of melting and fuel substitution** – maximizing the efficiency of use and selecting the best source of energy (e.g., electrical power or natural gas);
4. **Electric power management** – measures resulting in reduced electricity consumption, including power demand and power factor management, and cogeneration; and
5. **Heat recovery** – re-use of waste heat streams and their integration and prevention of heat losses in all forms (e.g., heat exchanger, insulation).

The influence of the first category, **organizational change**, on energy conservation is often hidden. The point is to try to even out the timing, type and size of production orders to achieve a more steady-state production output. Granted, this may be a tall order, but one in which the marketing and sales departments can help production staff a lot.

The **process change** category will probably be the largest and most capital intensive. The improvements include changes to throughput capacity, improved quality (product characteristics) and process controls but, typically, efficiency of energy utilization has not been the driving reason. This can be used to justify other projects and upgrade activities (e.g., variable speed drives, high-efficiency motors).

The **energy efficiency of melting and fuel substitution** category concerns improvement upgrades to burner systems, monitoring and control of flue gas composition, and furnace lining and insulation. Fuel substitution is a consideration dependent on fuel market availability (e.g., natural gas in Quebec) and cost prognosis, and the type of metal cast. It can have a beneficial impact on both castings quality and cost (e.g., using electricity in melting aluminum).

Electrical power management can improve the profit of the foundry quite significantly by controlling power demand and power factor, and by comprehensive monitoring and control of electrical energy consumption in general (see Monitoring and Targeting methodology, see Section 2.1.8, "Managing energy as raw material," page 30).

Heat recovery includes projects that are best viewed in the context of the entire foundry; several energy systems may be involved, and synergies are achievable.

3.2 Evaluating and calculating energy savings and other impacts of EMOs

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

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

Remember that the purpose of the evaluation is to determine 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 (use the classifications listed in Section 3.1), a table can be made up as shown in Table 6. The columns are self-explanatory, except the "Benefits-Cost" column, where annual energy saved per investment dollar is stated.

TABLE 6:
Long list of EMO projects

EMO project description	EMO No.	Type	Investment capital $1,000s	Energy savings GJ/yr.	Benefits-Costs GJ/yr./$	ROI years	Other implications of the project
Annealing oven optimization	35	PC	50	150 000	3	3.5	Output up 5%; heat re-use in preheating; re-size ductwork
Etc.							

3.3 Selecting and prioritizing EMO projects

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

- Assessing risks;
- Assessing costs;
- Doing the first thing first; and
- Using economic modeling to evaluate project trade-offs.

Initial scrutiny

Technical feasibility

The initial long list of EMO projects should now be scrutinized from several viewpoints. In addition to clearly impractical ideas, which can be rejected out-of-hand, the projects not meeting our criteria (very much of our own making, i.e., foundry-specific) should also be discarded. We will examine all available information, such as:

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

Possible synergies

Can the project be integrated advantageously with others to achieve heightened benefits (e.g., an upgrade of induction furnace cooling water together with improved space heating and ventilation)?

If so, try to quantify the benefits of the projects' interaction and compare these 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 proper because it is comprehensive. However, it is recognized that lack of necessary resources may force a foundry to implement a project without expending the time and effort required in comparing it to others. Once a project is seen as meeting the energy-savings requirements, clears all the other investment hurdles described here, there is no reason for delaying it. The advantage of this ad hoc approach is in the rapid implementation of projects, which start to provide ongoing energy savings.

Business risks

1. Balance perspectives from the point of view of safety, the environment, legal and regulatory factors and business and public image. Quantify the risk by using the formula

$$\mathbf{R = E \times L \times C}$$

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

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

See Appendix 5.6 for further details.

Business plan and priorities

The foundry's business plan (usually over several time horizons – short-, mid- and long-term) and priority objectives should also be considered.

"The key is not to prioritize what is on your schedule, but to schedule your priorities!" – STEVEN COVEY

Apply the "first things first" rule: put emphasis on a proactive, preventive approach to issues and projects, which will allow departure from the all-too-common fire fighting, crisis management mode of operations. In other words, ask, "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; and
   – Installation space.
2. Estimate the cumulative annual operating savings of the improvement project, such as:
   – Power, water, natural gas, compressed air, consumables; and
   – Maintenance, spare parts, labour.

   Of these, for energy conservation projects, the energy consumption is the most important. Note that compressed air, due to the high cost of energy involved in its generation, is considered separately.
3. Calculate the simple payback on investment and express it in years (months, if less than one year).

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

Risk

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

- **Financial** – Accounting and audit, insurability, credit, insolvency;
- **Organizational** – Corporate image, human relations;
- **External** – Market, social change, climate change;
- **Regulatory** – Regulations, governmental policies;
- **Legal** – Legislation, statutes, torts, contracts; and
- **Operational** – Production, environment, health and 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-Q850-97 Standard, *Risk Management Guideline for Decision-Makers*. To buy the guideline, load their website at www.csa.ca and then click on Welcome> Standards> Quality/Business Management> Online Store & Catalogue> Risk Management> Q850> CAN/CSA-Q850-97. The tables in Appendix 5.6, which will allow you to rate various risks quickly and simply, are based on this standard.

Costing of a project

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

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

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

When we have narrowed our choices to a particular solution, greater accuracy for a *formal project approval* process is required. It means that detailed engineering of the project, including drawings, schematic electrical, piping and duct diagrams, issuance of formal requests for proposal to multiple vendors, with all project specifications, etc., must be done. The typical relationships and anticipated accuracy levels are shown in Table 7.

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

TABLE 7:
Cost estimation accuracy

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

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 lie in speedy answers to multiple scenarios. The disadvantages include 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*," *Machine Design*, May, 1998). It is based on setting uncomplicated trade-off rules in project development. It recognizes that every project has four key objectives:

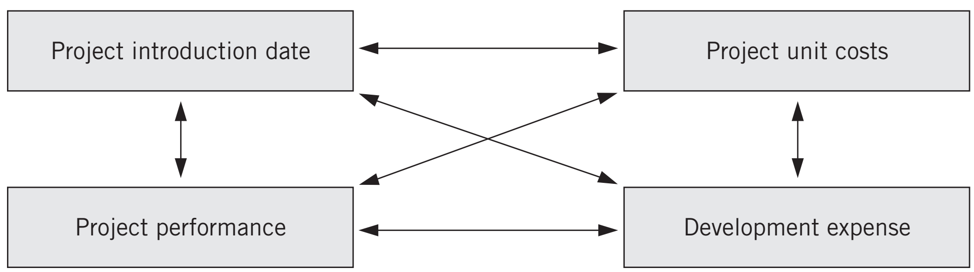
- Schedule – target date;
- Project unit cost;
- Project performance; and
- Development costs.

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

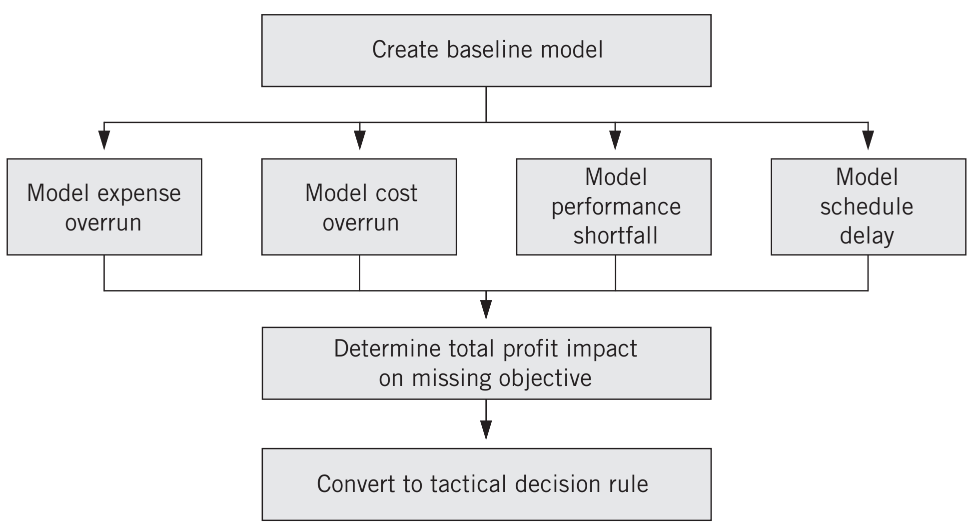
The *target date* is the date when the project should be fully on stream. The *product unit costs* are the implemented costs expressed based on product unit, or one tonne of metal cast, etc. The *project performance* measures the revenue stream over the project's lifetime from the saving/improved productivity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

The next step is to assign a dollar value to 1% change in each of those parameters. This is foundry-specific, something we can set as a rule of thumb very easily. We may now model, for example, a 50% overrun of development (i.e., equipment procurement and installation) expenses, a 10% overrun of production costs, a 10% performance shortfall, and a six-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).

Key economic objectives



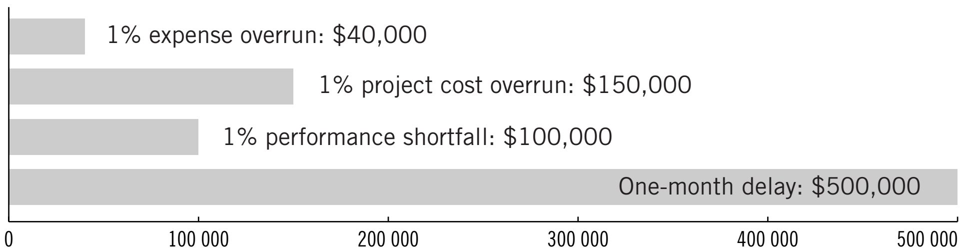
Creating trade-off rules



Charts after D. Reinertsen, Machine Design, May 1998

Tactical decision rules

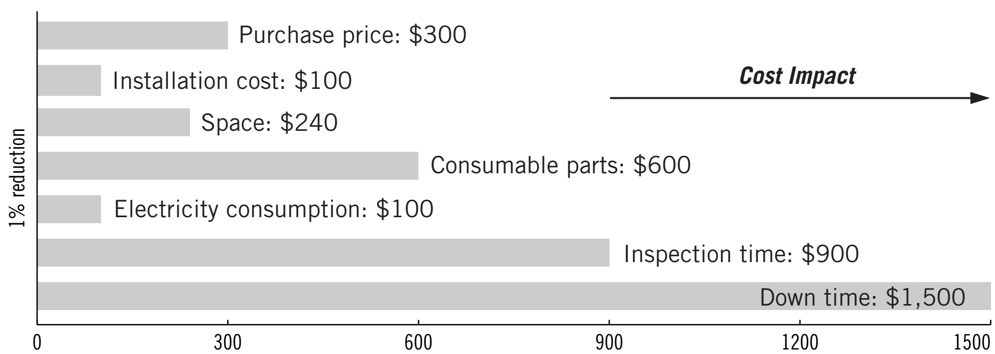
Life-cycle profit impact



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

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 down time – can be quantified and estimated, and total ownership cost can be expressed in dollars. This can be used to calculate the trade-off rules. In this case, reducing inspection time has nine times the impact of lowering electricity consumption.

Charts after D. Reinertsen, Machine Design, May 1998

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

Important note

A foundry can use this economic model in evaluating other types of projects as well. For instance, when contemplating new product development and possible trade-offs, substitute appropriate terms, such as market introduction date, product, etc., for the parameters used in the preceding examples.

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

A few tips on how to implement the economic modeling tool

- **Keep the financial model simple** – when input data is imprecise, do not fret over accuracy of product unit costs; use cumulative profit before taxes instead – this is something that is generally understood. Focus any extra effort on making the input data as accurate as possible.
- **Involve the right people** – different team members may have different critical information needed to construct the model; involve the financial controller for analytical as well as political reasons.
- **Make the trade-off rules visible** – post the key numbers (e.g., what is one hour of down time worth, etc.) so that 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 into your business process** – make the decision rules a part of every project (e.g., any new-product business plan, too!). Start every project with a consistently calculated and reviewed set of tactical decision rules.
- **Don't develop projects (products, etc.) unless you are ready to do the simple math!**

3.4 Developing energy management programs further

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

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

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

Setting energy conservation targets

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

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

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

Once a target has been met on a sustained basis over a period of several weeks, 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 work force in energy projects by giving them goals to achieve.

> Targets should be realistic, measurable and verifiable.

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

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 but true cliché: one has to walk before one can run! Start the program with projects that will bring in results quickly and rather easily – harvest the low-hanging fruit. That will be a great source of motivation to employees – to see that it can be done and that they are successful. It will give the members of the energy management team the confidence to start more complex and longer-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.

> Beware that, without ongoing attention, the low-hanging fruit may grow back and the initial effort will have been wasted!

3.5 Implementing, monitoring performance and continually improving

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

Action plans

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

Start the work early

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

Encourage the team members to keep up with their assigned work and to stick to the implementation schedule. Meet with the energy management committee 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 are the cost savings achieved from data gathered by the energy-monitoring system, and what is the return on investment?
- Are the implemented energy-saving measures living up to the projections? Problems with the project's performance can be identified and techniques for estimating costs and benefits of energy efficiency improvements for future projects can be improved.
- Is the equipment performing as per the supplier guarantees?
- Can we set future energy-use reduction targets and monitor progress toward new goals?
- Are there areas in the facility that 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. They are preferred, since they enable global comparisons. For example, state the energy consumption or savings in this way:

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

- Per tonne of good castings;
- Per tonne of melted metal;
- Per investment dollar;
- Per dollar of sales;
- As power (gas, steam, compressed air) saved; state also its equivalent in dollars;
- As annual operating cost savings; and
- As capital cost avoidance.

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

Lock in the gains – set new targets

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

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

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

Continually improve

Review the energy target once it has been met on a sustained basis over a period of several months. Then, it can become the new standard and a new, progressive target can be set. The step-wise target setting toward improving energy efficiency helps the managers to regard energy as a resource that must be managed with as much attention as other process inputs, such as labour and raw materials.

Effective communication

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

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

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

Stay away from a dry format of reporting – use a representation that people can understand. For example, express savings in dollars, dollars per employee or dollars per unit of production. Show savings on a cumulative basis; show how they contribute to the company's profit picture.

> Use simplified, graphic, visual representations of the results – use charts, diagrams, "thermometers" of fulfilment, etc.
> **Relate results to costs.**

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

Just as important is to keep the foundry 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.

4.0
Sources of Assistance

4.1 Government

Industrial Energy Innovators (IEI)

The IEI is a voluntary program to support the efforts of individual companies to improve energy efficiency and take action on climate change. NRCan registers the company as an Industrial Energy Innovator after the president or CEO of a company signs a letter of commitment to implement energy-saving measures in the organization. As part of its commitment, each participating company develops and implements an energy efficiency improvement target or goal-setting process and action plan, nominates an energy efficiency champion, and tracks and reports the results of its energy efficiency activities annually. In return, NRCan supports Industrial Energy Innovators with energy management workshops, seminars on new technologies and operating practices, sector-specific energy efficiency guide-books (such as this one), an international technical information network, an employee awareness tool kit and energy management newsletters.

Canadian Industry Program for Energy Conservation (CIPEC)

CIPEC, which receives core funding and administrative support from NRCan's Office of Energy Efficiency (OEE), provides the industry with a mechanism for obtaining the following types of assistance:

- Setting energy efficiency improvement targets for each sector and their sub-sectors;
- Publishing reports of accomplishments in energy efficiency improvements;
- Encouraging implementation of action plans at the sub-sector level;
- Promoting synergy between sectors through sectorial task forces;
- Giving energy managers a means by which to share expertise and contribute to the setting and meeting of energy efficiency goals for their sector and their companies; and
- Sector benchmarking.

Emerging Technologies Program (ETP)

The ETP helps industries identify and develop emerging energy-efficient technologies with significant potential to reduce energy consumption, limit emissions of greenhouse gases, improve manufacturing competitiveness and reduce the environmental impact of manufacturing processes. The ETP supports sector studies, technological assessments, field trials of technologies and research and development (R&D) activities. Contributions are repayable either from revenues or from cost savings realized from successful projects. The ETP also helps companies claim the 30% capital cost allowance on eligible energy-conserving and renewable-energy equipment.

Industry Energy Research and Development (IERD) Program

The IERD Program supports Canadian companies engaged in energy efficiency R&D. It focuses on promoting the development of products, processes or systems that will increase the efficiency of energy use by industry. IERD support generally takes the form of loans of up to 50% of the cost of the project, repayable when the product or process goes on the market.

Canada's Energy Efficiency Awards

Canada is a world leader in many aspects of energy efficiency, and it's important for us to celebrate and publicize our successes. That's the goal of Canada's Energy Efficiency Awards. Businesses, institutions, governments, communities and individuals – including students – are eligible. You can even nominate yourself!

Please visit the following Web site to learn about the awards and on how to get registered: http://oee. nrcan.gc.ca/awards/home.cfm.

Information Sources

For further information on the above and other programs, contact these government sources. (Please note: Every effort has been made to obtain the most up-to-date contact information possible.)

Philip B. Jago
Assistant Director
Industrial Programs Division
Canadian Industry
Program for Energy
Conservation and Industrial
Energy Innovators Program
Office of Energy Efficiency
Natural Resources Canada
580 Booth Street
Ottawa ON K1A 0E4
Tel.: (613) 995-6839
Fax: (613) 947-4121
E-mail: pjago@nrcan.gc.ca

Norm Benoit
Program Coordinator
Emerging Technologies Program
Canadian Centre for Mineral and
Energy Technology (CANMET)
1 Haanel Drive
Ottawa ON K1A 1M1
Tel.: (613) 996-6165
Fax: (613) 995-7868
E-mail: nbenoit@nrcan.gc.ca

Rudy Lubin
National Team CADDET
CADDET Canada
Natural Resources Canada
580 Booth Street, 13th Floor
Ottawa ON K1A 0E4
Tel.: (613) 996-6220
Fax: (613) 947-1016
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568 Booth Street
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E-mail: lwhiting@nrcan.gc.ca

Richard Fry
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IERD Secretariat
Natural Resources Canada
1 Haanel Dr.
Ottawa ON K1A 1M1
Tel.: (613) 996-0890
Fax: (613) 995-7868
E-mail: rifry@nrcan.gc.ca

Alan Bowles
Manager, Business Contracts
Mobile Foundry Laboratory
CANMET
568 Booth Street
Ottawa ON K1A 0G1
Tel.: (613) 995-8814
Fax :(613) 992-8735
E-mail: abowles@nrcan.gc.ca

Denise Mullen-Dalmer
Director,
Electricity Development Branch
Economic Development Division
Ministry of Employment and Investment
4 - 1810 Blanshard
Victoria BC V8W 9N3
Tel.: (250) 952-0264
Fax: (250) 952-0258
E-mail: denise.mullendalmer@gems1.gov.bc.ca

Terry E. Silcox
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Manitoba Conservation
1395 Ellice Ave, Suite 360
Winnipeg MB R3G 3P2
Tel.: (204) 945-2035
Fax: (204) 945-0586
E-mail: tsilcox@em.gov.mb.ca

Darwin Curtis
Director, Minerals and Energy Division
NB Natural Resources and Energy
PO Box 6000
Fredericton NB E3B 5H1
Tel.: (506) 453-3720
Fax: (506) 453-3671
E-mail: dcurtis@gov.nb.ca

Brian Maynard
Assistant Deputy Minister
Department of Mines and Energy
PO Box 8700
St. John's NF A1B 4J6
Tel.: (709) 729-2349
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E-mail: bmaynard@dnr.gov.nf.ca

Scott McCoombs
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PO Box 698
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Tel.: (902) 424-7305
Fax: (902) 424-7735
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John Rinella
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Energy Division
Ontario Ministry of Energy
Science and Technology
880 Bay Street, 3rd Floor
Toronto ON M7A 2C1
Tel.: (416) 325-7064
Fax: (416) 325-7023
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Nick Markettos
Manager
Science and Technology Awareness and Innovation
Ministry of Energy, Science and Technology
56 Wellesley St. West, 11th Floor
Toronto ON M7A 2E7
Tel.: (416) 314-2527
Fax: (416) 314-8224
E-mail: marketni@est.gov.on.ca

M. Luc Morin
Ministère des Ressources naturelles
Agence de l'efficacité énergétique
5700, 4e Avenue Ouest, B-405
Charlesbourg QC G1H 6R1
Tel.: (418) 627-6379, ext. 8036
Fax: (418) 643-5828
E-mail: luc.morin@aee.gouv.qc.ca

Howard Loseth
Energy Conservation Engineer
Energy Development Branch
Saskatchewan Energy and Mines
2101 Scarth Street
Regina SK S4P 4V4
Tel.: (306) 787-3379
Fax: (306) 787-2333
E-mail: howard.loseth@sem.gov.sk.ca

Andy Ridge
Senior Analyst, Climate Change Group
Alberta Department of Environment
North Petroleum Plaza, 14th Floor
9945 108th St.
Edmonton AB T5K 2G6
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Fax: (403) 427-2278
E-mail: andy.ridge@gov.ab.ca

Other links can be found in Section 4.7, "Internet" (page 113).

4.2 Canadian federal ON-SITE / À LA SOURCE professional employment assistance program

This program is mentioned separately because it gives low-cost professional help to companies that want to address process issues such as energy efficiency improvements, yet lack the resources to do that.

The Government of Canada's ON-SITE/À LA SOURCE program, sponsored by the Canadian Manufacturers & Exporters, is an industry-government partnership that:

- Provides job experience to unemployed professionals; and
- Helps employers address key environmental, energy and quality management challenges.

ON-SITE places qualified, unemployed professionals "on staff" but not "on salary." While working, they continue to draw unemployment insurance benefits and have access to training and technical support. At the end of an employee's ON-SITE term, which is usually six months, the employer has an option, but not an obligation, to hire the individual. Participating employers are requested to contribute up to $100 per week of their ON-SITE worker's term to defray the cost of the program, borne by the sponsor and the Employment Insurance Section 25 Job Creation Program.

The ON-SITE/À LA SOURCEl program is a "win-win" solution because:

- Employees contribute with their professional work experience and help project implementation while gaining new knowledge in a salary-free fashion;
- Employers get the job done at minimal expense because they need not add to staffing levels. They will also glean useful information and knowledge from the professionals and have a risk-free chance to evaluate their work should they want to eventually hire the persons.

4.3 Universities and colleges

The following post-secondary education institutions offer foundry-related programs:

St. Clair College
2000 Talbot Road West
Windsor ON N6A 6S4
Contact: Jamie Wilson
Tel.: (519) 966-2727, ext. 4431
Fax: (519) 972-2755

Mohawk College
135 Fennell Avenue West
Hamilton ON L8N 3T2
Contact: Don Burroughs
Tel.: (905) 575-2140
Fax: (905) 575-2414

Mohawk College offers eight courses through the CFA-sponsored Modern Foundry Technologies Institute.

The Modern Foundry Technologies Institute at Mohawk College is the only Canadian education institute that is sponsored by the U.S. Foundry Education Foundation.

University of Windsor
Mechanical and Materials Engineering
Light Metals Casting Technology
Windsor ON N9B 3P4
Tel.: (519) 253-3000, ext. 2596
Fax: (519) 973-7007
E-mail: mech@uwindsor.ca

Advanced foundry processes for lightweight castings, new generation foundry materials and solidification modeling

Fanshawe College
1460 Oxford Street East
London ON N5Y 5R6
Contact: Mike Westmorland
Tel.: (519) 452-4525
Fax: (519) 452-1343

Humber College
205 Humber College Boulevard
Etobicoke, ON M9W 5L7
Contact: Ken Simon
Tel.: (416) 675-6622, ext. 4567
Fax: (416) 674-7093

Conestoga College
299 Doon Valley Drive
Kitchener ON N2G 4M4
Contact: Hans Zawada
Tel.: (519) 748-5220, ext. 414
Fax: (519) 748-3521

Cambrian College
1440 Barrydowne Road
Sudbury ON P3A 3V8
Contact: Dave Marks
Tel.: (705) 566-8101
Fax: (705) 560-9652

Ryerson Polytechnic University
Mechanical Engineering Programs, Material Science
350 Victoria Street
Toronto ON M5B 2K3
Tel.: (416) 979-5000
Web site: www.ryerson.ca

Cégep de Trois-Rivières
Technologie de la métallurgie
3500, rue de Courval
C.P. 97
Trois-Rivières QC G9A 5E6
Tel.: (819) 376-1721
E-mail: webmaster@cegeptr.qc.ca

Materials testing, mechanical welding and tranformation processes

4.4 Utilities

Electrical

Alberta

Lloyd Berschi
EnVest®
E-mail: lqbertsc@epcor-group.com

Nap Pepin
ATCO Electric
E-mail: nap.pepin@atcoelectric.com

British Columbia

Murray Bond
BC Hydro
E-mail: murray.bond@bchydro.bc.ca

Derek Henriques
BC Hydro – PowerSmart®
E-mail: derek.henriques@bchydro.bc.ca

Manitoba

Brian Gaber
Winnipeg Hydro
E-mail: bgaber@city.winnipeg.mb.ca

Gerry Rose
Manitoba Hydro
E-mail: gwrose@hydro.mb.ca

New Brunswick

George Dashner
New Brunswick Power
E-mail: gdashner@nbpower.com

Blair Kennedy
New Brunswick Power
E-mail: bkennedy@nbpower.com

Newfoundland and Labrador

David Woolridge
Newfoundland Power
E-mail: dwoolrid@newfoundlandpower.com

Nova Scotia

Ann Hope
Nova Scotia Power Corporation
E-mail: ann.hope@nspower.ns.ca

Ontario

Scott Rouse
Ontario Power Generation Corp.
E-mail: srouse@ontariopowergeneration.com

Bob McKellar
Ontario Hydro Power
E-mail: bob.mckellar@ontariohydropower.com

Quebec

Ronald Martineau
Hydro-Québec
E-mail: martineau.ronald@hydro.qc.ca

Nicolas Nadeau
Hydro-Québec
E-mail: nicolas.nadeau@hydro.qc.ca

Saskatchewan

Randy Graham
SaskPower
E-mail: rgraham@saskpower.sk.ca

Prince Edward Island

Angus Orford
Maritime Electric Co. Ltd.
E-mail: orford@maritimeelectric.com

4.5 Associations

Natural gas

Alberta

Mark Antonuk
Canadian Western Natural Gas
E-mail: mark.antonuk@cwng.ca

British Columbia

Gary Hammer
BC Gas
E-mail: ghammer@bcgas.com

Manitoba

Gerry Rose
Manitoba Hydro (also for natural gas)
E-mail: gwrose@hydro.mb.ca

Ontario

Massoud Almassi
Enbridge
E-mail: massoud.almassi@cgc.enbridge.com

Marc St. Jean
Union Gas Ltd.
E-mail: mstjean@uniongas.com

Quebec

Robin Roy
Gaz Métropolitain
E-mail: rroy@gazmet.com

Saskatchewan

Bernard Ryma
SaskEnergy/TransGas
E-mail: bryma@saskeenrgy.sk.ca

Canadian Foundry Association
Judith Arbour, Executive Director
One Nicholas Street, Suite 1500
Ottawa ON K1N 7B7
Tel.: (613) 789-4894
Fax: (613) 789-5957
E-mail: judy@foundryassociation.ca
Web site: http://www.foundryassociation.ca

CIPEC Foundry Sector Task Force
Adam Promoli, Chairman
Crowe Foundry Limited
P.O. Box 25010
95 Sheffield St.
Cambridge ON N3C 4B1
Tel.: (519) 658-9376, ext. 241
Fax: (519) 658-6190
E-mail: adam@crowefoundry.com

American Foundry Society and Cast Metals Institute, Inc.
505 State Street
Des Plaines IL 60016-8399 U.S.A.
Tel.: 1 800 537-4237 (U.S. and Canada)
Fax: (847) 824-7848
Web site: http://www.afsinc.org

Publishers of Modern Casting, Engineering Casting Solutions and Casting Source Directory magazines

Casting Industry Suppliers Association
Web site: http://www.industry.net/c/orgindex/cisa

British Foundry Association
E-mail: webmaster@foundryonline.com

Canadian Die Casters Association
P.O. Box 1227, Station B
Ottawa ON K1P 5R3
Tel.: (613) 271-6164
Fax: (613) 599-7027
E-mail: cdcassn@istar.ca

Canadian Manufacturers & Exporters
5995 Avebury Road, Suite 900
Mississauga ON L5R 3P9
Tel.: (905) 568-8300
Fax: (905) 568-8330
E-mail: webmaster@cme-mec.ca

Other links can be found under Section 4.7, "Internet".

4.6 Consultants

For assistance, refer to the consultant listings in the local Yellow Pages™, advertisements in trade magazines, and lists of certified energy technologists and professional engineers in your province. Inquire also with other members of the foundry industry for references. An experienced consultant brings an independent set of eyes and can, as an outsider, quickly spot energy-wasting practices.

4.7 Internet

The Internet is a very rich information source. In addition to the Internet addresses stated earlier in the guidebook, here are some other useful contacts you may find on the Internet:

American Foundry Society
www.afsinc.org

California Cast Metals Association
www.foundryccma.org

Canadian Foundry Association
www.foundryassociation.ca

Canada's Climate Change Voluntary Challenge and Registry Inc.
www.vcr-mvr.ca/home_e.cfm

Castings Technology International
www.castingsdev.com

Casting Industry Suppliers Association
www.cisa.org

Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET)
An international "library" of information on energy projects.

Note: Each CADDET reference has embedded links.
www.caddet-ee.org/register/dataee

Compressed Air Challenge Energy Center of Wisconsin
(also provides training)
www.knowpressure.org

Diecasting Development Council
www.diecasting.org/ddc

Ductile Iron Marketing Group
www.ductile.org/dimg

Ductile Iron Society
www.ductile.org

Electric Power Research Institute
www.epri.com

FIRST (Foundry Industry Recycling Starts Today)
www.foundryrecycling.org

Foundry Educational Foundation
www.fefoffice.org

Heads-Up CIPEC information bulletin
http://buildings.nrcan.gc.ca/bulletins/cipec.htm

Illinois Cast Metals Association
www.ilcastmetals.org

Industrial Energy Innovators Initiative
http://oee.nrcan.gc.ca/cipec/ieep/

Industry Canada
http://strategis.ic.gc.ca

Investment Casting Institute
www.investmentcasting.org

Iron Casting Research Institute
www.ironcasting.org

Model National Energy Code for Buildings for Ontario
www.orderline.com/obc
Tel.: 1 888 361-0003 (toll-free)

Netherlands Energy Research Foundation
www.eco-web.com/register/00472.html

Non-Ferrous Founders' Society
www.nffs.org

North American Die Casting Association
www.diecasting.org

Oak Ridge National Laboratory
www.ornl.gov

Steel Founders' Society of America
www.sfsa.org

Texas Cast Metals Association
www.tcmainc.com

Tooling & Manufacturing Association (TMA)
www.tmanet.com

4.8 Other foundries

Please see Appendix 5.5 for a list of member foundries of the CFA.

5.0 Appendices

Appendix 5.1: Energy units and conversion factors

Basic SI units

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

Derived SI units

Volume:	hectolitre (**hL**)	100 L
	cubic metre (**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/m^2
	U-value	watt/m^2K
	Thermal conductivity (K)	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 (U.S.)
	L	0.035315	cubic feet
Energy:			
Quantity of heat:	kWh	3.6	MJ
	kWh	3412.0	Btu
	MJ	947.8	Btu
	Btu	0.001055	MJ
Heat emission or gain:	W/m^2	0.317	Btu/sq. ft.
Specific heat:	KJ/kgK	0.2388	Btu/lb.°F
Heat flow rate:	W	3.412	Btu/h
U-value, heat transfer coefficient:	W/m^{2}K	0.1761	Btu/sq. ft.h°F
Conductivity:	W/m K	6.933	Btu in./sq. ft.h°F
Calorific value (mass basis):	KJ/kg	0.4299	Btu/lb.
Calorific value (volume basis):	MJ/m^3	26.84	Btu/cu. ft.
Pressure:	bar	14.50	lb.ft./sq. in. (psi)
	bar	100	kPa
	bar	0.9869	std. atmosphere
	mm Hg (mercury)	133.332	Pa
	ft. of water	2.98898	kPa
Specific volume:	m^3/kg	16.02	cu. ft./lb.
Velocity:	m/s	3.281	ft./s

Useful values

1 Therm	=	100 000 Btu	or	29.31 kWh
1 cu. ft. of natural gas	=	1 000 Btu	or	0.2931 kWh
1 U.S. gal #2 oil	=	140 000 Btu	or	41.03 kWh
1 Imperial gal #2 oil	=	168 130 Btu	or	49.27 kWh
1 U.S. gal #4 oil	=	144 000 Btu	or	42.20 kWh
1 Imperial gal #4 oil	=	172 930 Btu	or	50.68 kWh
1 U.S. 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

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.

Appendix 5.2: Energy benchmarks in foundries

Measure		Unit	Iron foundries		Steel foundries		Brass and bronze foundries	
			Mean	Range	Mean	Range	Mean	Range
Cost of energy		$/t	138	67–193	230	110–425	386	100–830
Cost of electricity		$/t	72	–	186	–	300	–
		¢/kWh	9.5	6–13	7.9	6–12	10.2*	6–13
Cost of gas		$/t	–	–	33	–	68	–
Energy per tonne (t) in good castings		kWh/t	2395	1210–3310	4486	2200–6600	9590	2980–16100
Energy per tonne melted		kWh/t	1581	1025–2200	2710	1430–4740	4410	1870–11020
Ratio energy good castings: melted		–	1.51	–	1.66	–	2.17	–
Electricity per tonne in good castings		kWh/t	1555	1025–2870	2844	1320–4740	3417	2980–6400
Electricity per tonne melted		kWh/t	992	770–1290	1800	940–3090	1786	680–3350
Ratio electricity good castings: melted		–	1.57	–	1.58	–	1.91	–
Average load factor		%	30.1	16–70	31.3	13–50	26.6	14–41
Average power factor		%	87.0	73–99.6	92	84–99.7	89	73–94
Typical furnace electrical consumption	Per tonne melted	kWh/t	772	595–1290	872	620–2760	–	–
	Per tonne Cu melted	kWh/t	–	–	–	–	530	400–1100
	Per tonne Al melted	kWh/t	–	–	–	–	560	570–1610
Natural gas consumption	Per tonne Cu melted	kWh/t	–	–	–	–	4630	1870–11020
	Per tonne Al melted	kWh/t	–	–	–	–	4300	1540–7170
Furnace demand as % of plant's		%	78	68–89	68	59–88	59	33–90
Coil efficiency		1-k	80	63–95	78	70–82	58**	51–61
Power pack losses		%	11	8–15	12	8–20	12	8–25
Overall yield		%	66	54–84	58	49–67	53.2	36–73
Furnace el. cons./ plant cons.***		%	66	40–79	49	43–65	38.1	13–84

Notes: 1 t (tonne) = 2216 lb.; 1 ton (short) × 1.10233113 = 1 t; Cu = copper; Al = aluminum;
*Simple average 10.2 ¢/kWh; weighted average 9.5 ¢/kWh
**Cu furnaces
***Electricity consumption ratio

The table is an adapted composite from Laurence V. Whiting's studies of Canadian foundries, published in 2000.

Appendix 5.2: Energy benchmarks in foundries – Continued

Measure		Unit	Iron foundries		Steel foundries		Brass & bronze foundries	
			Mean	Range	Mean	Range	Mean	Range
Motors:	Demand	%	40	10–100 cupola 10–40 electric	34.6	20–49	45.5	20–80
	Consumption	%	30	–	47	–	–	–
	Average demand/nameplate	%	60	–	60	–	60	–
Compressor electrical cost of plant's		%	15.1	3–44	11.6	4–21	19.5	8–29 (75)
Gas burner efficiency:	Ladles	%	53	40–67	60.4	46–70	62	46–70
	Heat treat ovens	%	–	–	59	45–67	–	–
	Furnaces	%	–	–	–	–	58	40–70
Production:	Tonnes melted per foundry employee	t/man-month	9.9	3.3–18.7	5.4	2.2–11.4	4.11	1.07–10.80
	Tonnes shipped per total plant employee	t/man-month	6.0	2.2–14.3	2.6	1.3–6.4	0.89	0.36–4.08

The table is an adapted composite from Laurence V. Whiting's studies of Canadian foundries, published in 2000.

Appendix 5.3: Technical and energy usage characteristics of electric melting furnaces

Alloy and furnace type		Applied power kW	Holding power kW	Coil efficiency %	Melting temperature °C (°F)	Typical energy usage kWh/t	Melting requirements kWh/t*	Theoretical melting energy kWh/t**
Cast iron:	Channel	1100–1500	250–350	92–95	1482–1510 (2700–2750)	661–1213	–	–
	Main frequency	300–5500	40–220	60–78	1455–1537 (2650–2800)	573–882	550–595	374–398
	Medium frequency	425–3500	–	77–83	1455–1566 (2650–2850)	617–926	573–584	–
Steels:	Steel – Arc furnace	1000–1800	–	–	1593–1649 (2900–3000)	728–1075	–	–
	Stainless – medium frequency	250–1050	40	80–83	1621–1705 (2950–3100)	728–2205	628	383–406
Copper:	Channel	200–450	40–120	85–93	1177–1204 (2150–2200)	276–529	276–342	196–204
Aluminum:	Medium frequency	1500–1600	200–260	61–72	771 (1420)	705–827	540–551	327

Adapted from works of L.V. Whiting, using data from a joint CANMET and Ontario Hydro study of 25 foundries in Ontario (1991–1993).

Notes: 1 t (tonne) = 1.10233113 ton (short); 1 ton = 0.90716843 t
*Melting, and up to temperature without holding
**Theoretical melting energy refers to the temperature specified

Appendix 5.4: Calculating reductions in greenhouse gas emissions

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

On-site combustion systems

Use the data in Table 1 and the information given below to calculate the amount of CO_2, CH_4 and NO_x produced by combustion systems in the following example. To perform this calculation for your own facilities, obtain precise data from your natural gas utility.

- When the soaking pit in a steel mill was re-insulated, the original natural gas burners were retrofitted with high-efficiency burners. Annual fuel savings are estimated at 50 terajoules (TJ). What would be the corresponding reductions in CO_2, CH_4 and NO_x emissions?
- The emissions factors for natural gas fuel are CO_2: 49.68 t/TJ; CH_4: 0.13-1.27 kg/TJ; NO_x: 0.62 kg/TJ. A range of 0.13–1.27 kg/TJ has been indicated for CH_4, so we will assume 0.6 kg/TJ for this calculation.

  CO_2 reduction = 50 TJ/yr. × 49.68 t
  CO_2/TJ = 2 484 t/yr.
  CH_4 reduction = 50 TJ/yr. × 0.6 kg
  CH_4/TJ = 30 kg/yr.
  NO_x reduction = 50 TJ/yr. × 0.62 kg
  NO_2/TJ = 31 kg/yr.

TABLE 1

Greenhouse Gas Emissions Factors by Combustion Source

(The table continues on the next page)

Fuel type	CO_2		CH_4		NO_x	
Gaseous fuels	**t/ML**	**t/TJ**	**kg/GL**	**kg/TJ**	**kg/ML**	**kg/TJ**
Natural gas	1.88	49.68	4.8–48	0.13–1.27	0.02	0.62
Still gas	2.07	49.68	–	–	0.02	0.62
Coke oven gas	1.60	86.00	–	–	–	–
Liquid fuels	**t/kL**	**t/TJ**	**kg/kL**	**kg/TJ**	**kg/kL**	**kg/TJ**
Motor gasoline	2.36	67.98	0.24–4.20	6.92–121.11	0.23–1.65	6.6–47.6
LPGs	1.11–1.76	59.84–61.38	0.03	1.18	0.23	9.00–12.50
Diesel oil	2.73	70.69	0.06–0.25	1.32–5.7	0.13–0.40	3.36–10.34
Light oil	2.83	73.11	0.01–0.21	0.16–5.53	0.13–0.40	3.36–10.34
Heavy oil	3.09	74.00	0.03–0.12	0.72–2.88	0.13–0.40	3.11–9.59
Petroleum coke	4.24	100.10	0.02	0.38	–	–

Fuel type	CO_2		CH_4		NO_x	
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
U.S. bituminous	2.46–2.50	81.6–85.9	0.02	varies	0.1–2.11	varies
Canadian bituminous	1.70–2.52	94.3–83.0	0.02	varies	0.1–2.11	varies
Sub-bituminous	1.74	94.30	0.02	varies	0.1–2.11	varies
Lignite	1.34–1.52	93.8–95.0	0.02	varies	0.1–2.11	varies
Coke	2.48	86.00	–	–	–	–
Fuel wood	1.47	81.47	0.15–0.5	0.01–0.03	0.16	8.89

Abbreviations: t: tonne; kg: kilogram; g: gram; ML: megalitre; TJ: terajoule; kL: kilolitre; GL: gigalitre. (See Appendix 5.1: Energy units and conversion factors.)

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

Impact of reductions in electrical consumption

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

Using Table 1 and the information given below, calculate emissions reductions. To perform this calculation for your own facilities, obtain precise data from your electrical utility.

- At a large manufacturing plant in Saskatchewan, the energy management program involved replacing fluorescent light fixtures with metal halide fixtures and replacing several large electric motors with high-efficiency motors. The total annual energy saving was 33 600 MWh. Calculate the corresponding reduction in emissions.
- Table 2 shows that, in Saskatchewan, the average CO_2 emissions from electrical power generation is 0.83 t/MWh.
- Convert to equivalent energy saving at the generating station using a transmission efficiency of 96%.

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

CO_2 reduction = 35 000 MWh/yr. × 0.83 t/MWh
= 29 050 t/yr.

TABLE 2

Average CO_2 Emissions for 1998, by Unit of Electricity Produced

	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	0.88	245.3
British Columbia	0.03	7.5
Northwest and Yukon Territories	0.40	109.8
Canada average	0.22	61.1

Source: Demand, Policy and Analysis Division, Office of Energy Efficiency, Natural Resources Canada.

Appendix 5.5: Member foundries of the Canadian Foundry Association, by metal type cast

The following list was accurate on March 16, 2002, and is a source of possible further information. You can find contact details on the Internet through the CFA Web site, at www.foundryassociation.ca.

		Total
Alloy Irons		**3**
A.G. Anderson Ltd.	London, ON	
Molten Metallurgy Inc.	Paris, ON	
Wells Foundry Limited	London, ON	
Alloy Steels		**2**
A.G. Anderson Ltd.	London, ON	
Molten Metallurgy Inc.	Paris, ON	
Aluminum		**9**
Custom Aluminum Limited	Cambridge, ON	
Diversa Cast Technologies Inc.	Guelph, ON	
Gamma Foundries Ltd.	Richmond Hill, ON	
Grenville Castings Ltd. (Merrickville)	Merrickville, ON	
Grenville Castings Ltd. (Smiths Falls)	Smiths Falls, ON	
Niagara Bronze Limited	Niagara Falls, ON	
Paber Aluminum	Cap-Saint-Ignace, QC	
Pacific Mako	Langley, BC	
Ramsden Industries Limited	London, ON	
Aluminum Bronze		**1**
Niagara Bronze Limited	Niagara Falls, ON	
Beryllium Copper		**1**
Niagara Bronze Limited	Niagara Falls, ON	
Brass		**2**
Gamma Foundries Ltd.	Richmond Hill, ON	
Pacific Mako	Langley, BC	
Bronze		**4**
A.H. Tallman Bronze Ltd.	Burlington, ON	
Gamma Foundries Ltd.	Richmond Hill, ON	
Niagara Bronze Limited	Niagara Falls, ON	
Pacific Mako	Langley, BC	
Carbon		**6**
Canada Alloy Castings Ltd	Kitchener, ON	
Canadian Steel Foundries Ltd.	Montréal, QC	
Dominion Castings Limited	Hamilton, ON	
ESCO Limited	Port Coquitlam, BC	
Maritime Steel & Foundries Ltd.	New Glasgow, NS	
Molten Metallurgy Inc.	Paris, ON	

Copper Based Alloys		**1**
A.H. Tallman Bronze Ltd.	Burlington, ON	
Ductile Irons		**14**
Ancast Industries Ltd.	Winnipeg, MB	
Bibby Ste. Croix	Sainte-Croix, QC	
Brown Foundry	Morrisburg, ON	
Crowe Foundry Ltd.	Cambridge, ON	
Diversa Cast Technologies Inc.	Guelph, ON	
Fonderie Grand-Mère	Grand-Mère, QC	
Lethbridge Iron Works Company Ltd.	Lethbridge, AB	
McLean Foundry Limited	Brantford, ON	
Molten Metallurgy Inc.	Paris, ON	
Procast Foundries Inc.	Elmira, ON	
Standard Induction Castings Inc.	Windsor, ON	
Wabi Iron & Steel Corporation	New Liskeard, ON	
Wabtec Foundry Limited	Wallaceburg, ON	
Wells Foundry Limited	London, ON	
Grey Irons		**18**
Ancast Industries Ltd.	Winnipeg, MB	
B.P.I. – Sudbury	Sudbury, ON	
Bibby Ste. Croix	Sainte-Croix, QC	
Brown Foundry	Morrisburg, ON	
Crowe Foundry Ltd.	Cambridge, ON	
Dana Brake Parts Inc.	St. Catharines, ON	
Diversa Cast Technologies Inc.	Guelph, ON	
Fonderie Grand-Mère	Grand-Mère, QC	
Fonderie Laperle Inc.	Saint-Ours, QC	
Hopper Foundry (1977) Limited	Forest, ON	
Lethbridge Iron Works Company Ltd.	Lethbridge, AB	
McLean Foundry Limited	Brantford, ON	
Molten Metallurgy Inc.	Paris, ON	
Procast Foundries Inc.	Elmira, ON	
Standard Induction Castings Inc.	Windsor, ON	
Wabi Iron & Steel Corporation	New Liskeard, ON	
Wabtec Foundry Limited	Wallaceburg, ON	
Wells Foundry Limited	London, ON	
High Alloys Steel		**3**
AMSCO Cast Products (Canada) Inc.	Selkirk, MB	
Molten Metallurgy Inc.	Paris, ON	
Wescast Industries Inc. (Magalloy)	Stratford, ON	
High Chromium Alloy		**2**
Lethbridge Iron Works Company Ltd.	Lethbridge, AB	
Magotteaux Canada	Magog, QC	
High Conductivity Copper		**1**
Niagara Bronze Limited	Niagara Falls, ON	

Iron		**21**
A.G. Anderson Ltd.	London, ON	
Ancast Industries Ltd.	Winnipeg, MB	
B.P.I. – Sudbury	Sudbury, ON	
Bibby Ste. Croix	Sainte-Croix, QC	
Crowe Foundry Ltd.	Cambridge, ON	
Dominion Castings Limited	Hamilton, ON	
Fonderie Grand-Mère	Grand-Mère, QC	
Fonderie Laperle Inc.	Saint-Ours, QC	
Ford Motor Company	Dearborn, MI, U.S.A.	
Ford Motor Company of Canada Ltd. (WC)	Windsor, ON	
Hopper Foundry (1977) Limited	Forest, ON	
Lethbridge Iron Works Company Ltd.	Lethbridge, AB	
Magotteaux Canada	Magog, QC	
McLean Foundry Limited	Brantford, ON	
Procast Foundries Inc.	Elmira, ON	
Standard Induction Castings Inc.	Windsor, ON	
Wabi Iron & Steel Corporation	New Liskeard, ON	
Wabtec Foundry Limited	Wallaceburg, ON	
Wells Foundry Limited	London, ON	
Wescast Industries Inc. (Brantford)	Brantford, ON	
Wescast Industries Inc. (Wingham)	Wingham, ON	
Leaded Tin Bronzes		**2**
Gamma Foundries Ltd.	Richmond Hill, ON	
Niagara Bronze Limited	Niagara Falls, ON	
Low Alloy Steel		**10**
AMSCO Cast Products (Canada) Inc.	Selkirk, MB	
Canada Alloy Castings Ltd	Kitchener, ON	
Canadian Steel Foundries Ltd.	Montréal, QC	
Dominion Castings Limited	Hamilton, ON	
ESCO Limited	Port Coquitlam, BC	
ESCO Limited	Port Hope, ON	
Kubota Metal Corporation – Fahramet Division	Orillia, ON	
Maritime Steel & Foundries Ltd.	New Glasgow, NS	
Wabi Iron & Steel Corporation	New Liskeard, ON	
Wescast Industries Inc. (Magalloy)	Stratford, ON	
Manganese Bronze		**4**
AMSCO Cast Products (Canada) Inc.	Selkirk, MB	
ESCO Limited	Port Coquitlam, BC	
Gamma Foundries Ltd.	Richmond Hill, ON	
Niagara Bronze Limited	Niagara Falls, ON	
Nickel Bronze		**1**
Niagara Bronze Limited	Niagara Falls, ON	

Ni-Hard		**3**
Hopper Foundry (1977) Limited	Forest, ON	
Wabi Iron & Steel Corporation	New Liskeard, ON	
Wells Foundry Limited	London, ON	
Non-Ferrous		**11**
A.G. Anderson Ltd.	London, ON	
A.H. Tallman Bronze Ltd.	Burlington, ON	
BAYCO Industries	Winnipeg, MB	
Custom Aluminum Limited	Cambridge, ON	
Gamma Foundries Ltd.	Richmond Hill, ON	
Grenville Castings Ltd. (Merrickville)	Merrickville, ON	
Nemak Canada Inc.	Windsor, ON	
Niagara Bronze Limited	Niagara Falls, ON	
Paber Aluminum	Cap-Saint-Ignace, QC	
Pacific Mako	Langley, BC	
Ramsden Industries Limited	London, ON	
Stainless Steel		**7**
Canada Alloy Castings Ltd	Kitchener, ON	
Canadian Steel Foundries Ltd.	Montréal, QC	
ESCO Limited	Port Hope, ON	
Midan Industries Limited	Langley, BC	
Molten Metallurgy Inc.	Paris, ON	
Niagara Bronze Limited	Niagara Falls, ON	
Wabi Iron & Steel Corporation	New Liskeard, ON	
Steel		**16**
A.G. Anderson Ltd.	London, ON	
AMSCO Cast Products (Canada) Inc.	Selkirk, MB	
Canada Alloy Castings Ltd	Kitchener, ON	
Canadian Steel Foundries Ltd.	Montréal, QC	
Dominion Castings Limited	Hamilton, ON	
ESCO Corporation	Portland, OR, U.S.A.	
ESCO Limited	Port Hope, ON	
ESCO Limited	Port Coquitlam, BC	
Griffin Canada	Winnipeg, MB	
Kubota Metal Corporation – Fahramet Division	Orillia, ON	
Maritime Steel & Foundries Ltd.	New Glasgow, NS	
Midan Industries Limited	Langley, BC	
Molten Metallurgy Inc.	Paris, ON	
Niagara Bronze Limited	Niagara Falls, ON	
Wabi Iron & Steel Corporation	New Liskeard, ON	
Wescast Industries Inc. (Magalloy)	Stratford, ON	

Appendix 5.6: Risk evaluation tables

The following tables below serve as another decision-making tool in the selection and evaluation of EMO projects. They are generally applicable to a host of situations. Remember, risk R = E × L × C, where C is the sum of individual consequences (business, safety, etc.).

Risk map

		Severity: Losses to people, business, assets, production, environment		
		Minor	**Moderate**	**Major**
Probability:	**Frequent**	B	A	A – High (Act within three months)
	Seldom / occasionally	C	B – Medium (Act within six months)	A
	Rare	C – Low (Act within one year)	C	B

Risk values and weights

Risk component	Value scale	Weights
Exposure	0–10	1
Likelihood	0.1–10	1
Consequences	0.25–25	Total 10: 2.5 for each consequence

Likelihood

What is the probability that the event will take place?		
10	High	Continuous (may occur on a daily basis)
6	Medium high	Frequent (may occur on a weekly basis)
3	Medium	Occasional (may occur on a monthly basis)
1	Medium low	Rare (may occur on a yearly basis)
0.5	Low	Very rare (may occur only every few years)
0.1	None	Negligible

Exposure

How frequently does the activity or event take place?		
10	High	Continuous (Occurs throughout the day or daily)
6	Medium high	Frequent (Occurs weekly)
3	Medium	Occasional (Occurs monthly)
1	Medium low	Rare (Occurs yearly)
0.5	Low	Very rare (Occurs only every few years)
0	None	No exposure

Consequences

Public opinion / Company reputation			**Business**		
What are the impacts on public opinion and company reputation resulting from the activity or event and its aftermath?			What are the business consequences and/or financial losses resulting from the activity or event and its aftermath?		
Degree	**Description**	**Score**	**Degree**	**Description**	**Score**
High	Negative national or international news coverage, or protest by national or international protest groups or non-governmental organizations (NGOs) due to high importance issues Requires lengthy negotiations; issues may not be resolvable	**25**	**High**	Loss or damage of over $1,000,000 Significant long-term impact on: • Production costs, and/or • Ability of the plant to operate Permanent loss of new economic opportunities	**25**
Medium High	Negative local or regional news coverage or protests by local or regional stakeholders or non-governmental organizations (NGOs) Issues resolvable but require many meetings over several weeks or months	**10**	**Medium High**	Loss or damage of over $100,000 Significant short-term impact on: • Production costs, and/or • Ability of the plant to operate Short-term loss or restrictions on development of present and new economic opportunities	**10**
Medium	Complaints to outside agencies, regulators and the company Issues resolvable in short-term at meetings	**4**	**Medium**	Loss or damage of over $10,000 Slight impact on: • Production costs, and/or • Ability of the plant to operate Short-term restrictions on present economic opportunities	**4**
Medium low	Complaints to the company Issues easily resolved	**2**	**Medium low**	Loss or damage of over $1,000 No effect on: • Production costs, and/or • Ability of the plant to operate No restrictions on present and future new economic opportunities	**2**
Low	Second-hand knowledge of public concern	**1**	**Low**	Loss or damage of over $100	**1**
None	No complaints known	**0.25**	**None**	None	**0.25**

Consequences – safety

What are the human health and safety consequences of the activity or event and its aftermath?

Degree	Description	Score
High	Death(s) or long-term health impacts	**25**
Medium high	Serious injury or short-term health impacts	**10**
Medium	Temporary irritation or disability	**4**
Medium low	Series of minor injuries or complaints	**2**
Low	Minor first aid or irritation	**1**
None	None, negligible or inconsequential	**0.25**

Other categories of consequences may be chosen and similarly rated, e.g., environmental, legal, etc.

Hazard must be present for risk calculation and when it is expressed as frequency. It is called "Exposure" here.

Appendix 5.7: Energy management series of NRCan publications

The "Energy Management" series is a string of brief monographs, published by Natural Resources Canada over the past decade. All brochures have been reviewed by an engineer in the appropriate discipline. While in some brochures certain aspects, including most references to energy prices and capital costs, are no longer current, the basic theory and work examples remain valid and instructive.

Purchase price is only $4 per manual + 7% GST. Please make cheques payable to the Receiver General for Canada.

M91-6/01E – Process Insulation
M91-6/04E – Energy Accounting
M91-6/06E – Boiler Plant Systems
M91-6/07E – Process Furnaces, Dryers and Kilns
M91-6/08E – Steam and Condensate Systems
M91-6/09E – Heating and Cooling Equipment
M91-6/10E – Heating, Ventilation and Air Conditioning
M91-6/11E – Refrigeration and Heat Pumps
M91-6/12E – Water and Compressed Air Systems
M91-6/13E – Fans and Pumps
M91-6/14E – Compressors and Turbines
M91-6/15E – Measuring, Metering and Monitoring
M91-6/17E – Material Handling and On-Site Transportation Equipment
M91-6/18E – Architectural Considerations
M91-6/19E – Thermal Storage
M91-6/20E – Waste Heat Recovery

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Appendix 5.8: Information review

The following sources complemented the development of this guidebook, and the use of selected information from them in the text is gratefully acknowledged.

Heads Up CIPEC – Focus on Foundries, Office of Energy Efficiency, Natural Resources Canada, August 1999.

Proceedings of annual general meeting, Canadian Foundry Association, 2000.

Report on Preliminary Consultations – Canadian Metalcasting Technology Roadmap – Industry Canada, Canadian Foundry Association, Canadian Die-Casters Association, Canada Centre for Mineral and Energy Technology, et al. Draft, May 1999.

Private communications, Laurence V. Whiting, Canadian Centre for Mineral and Energy Technology, October through December 2000.

Use of electricity in Canadian iron foundries, Laurence V. Whiting, Canadian Centre for Mineral and Energy Technology, June 2000.

Use of electricity in Canadian steel foundries, Laurence V. Whiting, Canadian Centre for Mineral and Energy Technology, June 2000.

Use of electricity in Canadian bronze foundries, Laurence V. Whiting, Canadian Centre for Mineral and Energy Technology, May 2000.

The cost of melting grey cast iron in induction furnaces, L.V. Whiting, R.D. Warda, P.J. Buttle and R.G. Anstie, Electric Furnace Conference proceedings, 1988.

Process, Equipment and Techniques for the Energy-Efficient Recycling of Aluminum, F.T. Gerson Limited, Canadian Centre for Mineral and Energy Technology, February 1993.

Natural gas applications for industry – hydrogen, T.J. McCann and Associates Ltd., Canadian Centre for Mineral and Energy Technology, April 1996.

Natural gas applications for industry – iron and steel foundries, T.J. McCann and Associates Ltd., Canadian Centre for Mineral and Energy Technology, April 1996.

Natural gas applications for industry – steel industry, T.J. McCann and Associates Ltd., Canadian Centre for Mineral and Energy Technology, April 1996.

Natural gas applications for industry – overview, T.J. McCann and Associates Ltd., Canadian Centre for Mineral and Energy Technology, April 1996.

Intelligent energy management for small boiler plants, Gas Technology Canada, Canadian Centre for Mineral and Energy Technology, March 1998.

Implementation of an effective mill wide energy-monitoring system, Peter Brenndorfer, Avenor Inc., Canadian Centre for Mineral and Energy Technology, December 1996.

Analyses series, Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) – Learning from experiences with … :

- …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; and
- …industrial electric motor drive systems, 1998.

Low-NO_x technology assessment and cost/benefit analysis, Federal Industrial Boiler Program, Canadian Centre for Mineral and Energy Technology, October 1994.

Boilers and heaters – improving energy efficiency, Office of Energy Efficiency, Natural Resources Canada, 2001.

Success Stories, Canadian Industry Program for Energy Conservation, 2000–2001.

Annual report, Canadian Industry Program for Energy Conservation, 1999–2000.

Improving energy performance in Canada, Natural Resources Canada, 1999–2000.

The state of energy efficiency in Canada in 2001, Office of Energy Efficiency, Natural Resources Canada.

Foundry energy management, American Foundrymen's Society, 1982.

Tips for energy managers, Office of Energy Efficiency, Natural Resources Canada, 1998.

Energy efficiency planning and management guide, Canadian Industry Program for Energy Conservation (CIPEC), Office of Energy Efficiency, Natural Resources Canada, 2002.

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Development of Energy Intensity Indicators for Canadian Industry, 1990–1996, The Canadian Industrial Energy End-Use Data and Analysis Centre, Simon Fraser University, B.C., 1997.

Statistics Canada, selected information, 2000.

Best Practice Program, Guide 126, Compressing air costs, Energy Efficiency Office of Department of Energy, U.K., 1991.

International standards for environmental management systems ISO 14001:1996 and ISO 14004:1996, International Organization for Standardization, Geneva.

International standards for quality management systems ISO 9000:1994 and ISO 9001: 2000, International Organization for Standardization, Geneva.

Energy efficiency opportunities in … – 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; and
- …in aluminum smelters, Soprin-ADS, Aluminum Association of Canada, April 1998.

Analysis reports by CADDET, made available through the Office of Energy Efficiency, Natural Resources Canada:

- Small-scale cogeneration, AR 01;
- Process heating in the metals industry, AR 11;
- Process heating in low and medium temperature ranges, AR 22;
- Industrial heat pumps, AR 23;
- Industrial electric motor drive systems, AR 24; and
- Compact heat exchangers, AR 25.

Excerpts from 122 reports on various energy-using systems and novel foundry practices, extracted from CADDET's on-line register (http://www.caddet-ee.org):

- Energy efficient design of a new production facility at Scan Coat A/S, Denmark, 2000;
- Computer-aided advance runner design, U.K., 2000;
- Mechanical grit blasting of steel constructions without compressed air, The Netherlands, 1997;
- Heat treatment furnace using pulse firing, Canada, 1997;
- Heat recovery in an iron foundry at Sperre St. Yperi, Norway, 1995;
- Regenerating fluxing fluids in thermal galvanization, The Netherlands, 2000;
- Heat recovery in galvanizing foundries, The Netherlands, 2000;
- Heat recovery by means of a rotary heat exchanger in an iron foundry, Norway, 1995;
- The use of computerized modeling and solidification simulation at Hanson Foundry (Stockport) Ltd., U.K., 1994;
- Reclamation of foundry sand using natural gas, Canada, 1999;
- Use of molten metal filters in non-ferrous foundries, U.K., 1996;
- Variable speed drive on a large continuous furnace combustion air fan, U.K., 1994;
- Gas-fired scrap preheater in an iron foundry, Canada, 1999;
- Foundries benefit from new infrared mold coating dryer, U.S.A., 1996;
- Efficient continuous heat treatment furnace for metal products, Japan, 1997;
- Continuous ring foundry process for brass, The Netherlands, 1997;
- Ceramic insulation replaces firebrick in metal heat treating electric furnaces, U.S.A., 1997;
- Lost foam casting, U.S.A., 2000;
- Ladle lining with a lightweight insulating refractory material, U.K., 2000;
- Compressed air costs reduced by automatic control system, U.K., 1995;

- 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;
- Ultrasonic detection of compressed air leaks, Australia, 1999;
- Heat recovery from an air compressor, New Zealand, 1995;
- The performance of a variable speed air compressor, U.K., 2000;
- 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;
- Fuel-based nitrogen generator demonstrated in a metal industry, U.S.A., 1995;
- A monorail transport system at a galvanizing foundry, The Netherlands, 2000;
- Installation of a chiller and four rotary-drum air dryers, Canada, 2000;
- 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;
- Energy management system at Volvo-Car, The Netherlands, 1996;
- Supersavers: a workforce-led initiative to save energy and reduce waste, U.K., 2000;
- Energy monitoring system, Canada, 1999;
- Energy efficiency from induction melting technology, Australia, 1999;
- Gas-fired furnaces for light alloy melting and holding processes, U.K., 1994;
- Use of dual function burner and oxygen lance in an electric arc furnace, U.K., 1995;
- Regenerative type heat recuperation in a retort furnace, Canada, 1997;
- The use of oxygen/natural gas-fired burners on an electric arc furnace, U.K., 1996;
- Long campaign hot-blast cupolas in iron foundries, U.K., 1999;
- Cupola melting of cast iron, U.K., 1994;
- Electric induction furnaces replace coke-fired cupolas for iron melting and lower foundry energy, U.S.A., 1991;
- Electromagnetic induction furnace at Fonderie Grand-Mère Ltée, Canada, 1999;
- Gas-fired furnaces for light alloy melting and holding processes, U.K., 1994;
- Arkansas aluminum mould and die casting producer installs electric resistance melting furnaces, U.S.A., 1996;
- Coreless induction furnaces provide flexibility and energy savings in batch melting of iron, U.S.A., 1996;
- The conversion of two coke-fired cupolas to cokeless (gas-fired) melting at Hunt Bros. (Oldbury) Ltd., U.K., 1996;
- Replacing a coke-fired crucible furnace with a natural gas/oxygen drum furnace, The Netherlands, 1997;
- Speed controlled flue gas blower in an aluminum factory, The Netherlands, 1992;
- Saving energy by partial ventilation of spraying booths, The Netherlands, 1994;
- Improving dust collection systems at an aluminum plant, U.S.A., 1999;

- Raising employees' awareness at Rover Group Ltd., U.K., 1995;
- Energy and utility management at the Royal Mint, U.K., 1994;
- A Biotox installation at an anode preparation plant, Canada, 1999;
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The use of the above listed sources is also recommended to any reader wishing to obtain further information.

Leading Canadians to Energy Efficiency at Home, at Work and on the Road

The Office of Energy Efficiency of Natural Resources Canada
strengthens and expands Canada's commitment to energy efficiency
in order to help address the challenges of climate change.

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