CIPEC

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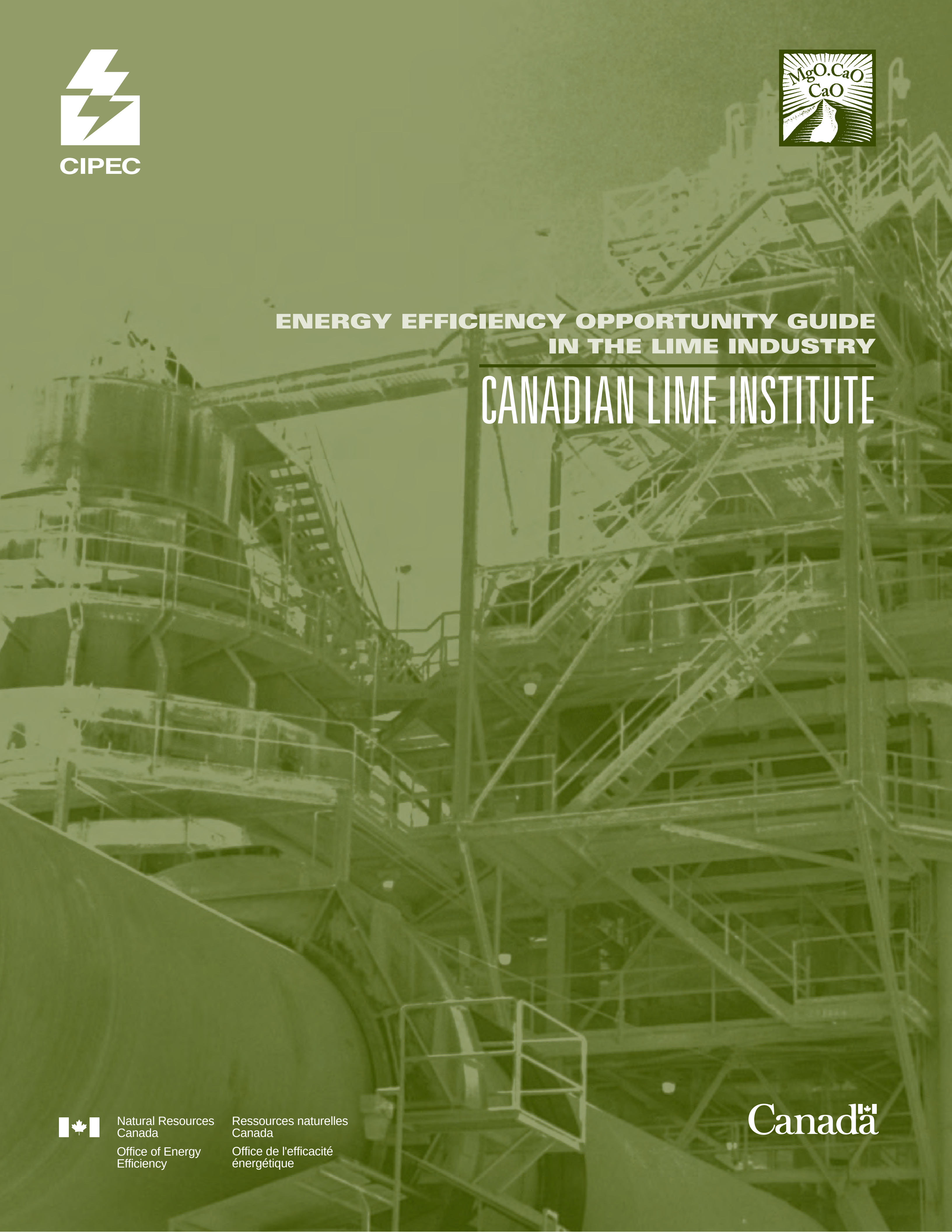

ENERGY EFFICIENCY OPPORTUNITY GUIDE IN THE LIME INDUSTRY

CANADIAN LIME INSTITUTE

Natural Resources Canada
Ressources naturelles Canada
Office of Energy Efficiency
Office de l'efficacité énergétique

Canada

Energy Efficiency Opportunity Guide in the Lime Industry – Canadian Lime Institute

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Natural Resources Canada
580 Booth Street, 18th Floor
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The CLI is a self-governing body with representatives of 16 lime-producing sites in Canada.

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- Steve Hood, AERA Energy Solutions Group, Guelph, Ontario
- Don Taylor, Lafarge Lime, Dundas, Ontario

Energistics Group Inc. is a privately owned, full energy service provider that provides management, consulting and research services focusing on the cost-effective purchase and use of utilities to producers, utilities and end-users. We can be contacted at the following:

Energistics Group Inc.
300 Richmond Street, Suite 104
Chatham ON N7M 1P7
Telephone: (519) 351-2104
Facsimile: (519) 351-2146

Neal Cockshutt
Director, Energy Services
Energistics Group Inc.

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[1] During the analysis of this project, Global Stone Ingersoll formally became Ingersoll Lime Limited.

TABLE OF CONTENTS

1.1 INTRODUCTION TO THIS GUIDE

This Guide has been developed as a practical source of information for lime processors and calcining personnel in Canada. Designed to be user-friendly, it suggests potential areas of energy, utility and associated cost savings for lime facilities and processing operations.

It has been assumed that readers are familiar with lime-processing operations and have the ability to adapt energy-saving tips to their individual applications and specific sites.

Purchased energy is not necessarily a fixed business expense because its cost can be reduced through conservation techniques. This Guide can be used as a quick reference to develop self-audit and evaluation techniques to monitor energy usage.

1.2 INTRODUCTION TO CONSERVATION AND EFFICIENCY

Two basic terms are often used interchangeably when discussing improvements in how much energy is used or how much can be saved – “energy conservation” and “energy efficiency.” Each has a slightly different meaning, but both approaches result in reducing the total quantity of energy consumed. Whichever approach is used, it is important to consider the impacts that efficiency and conservation measures have on production rates and product quality.

Energy conservation refers to measures that reduce the total amount of energy consumed. This typically relates to reducing wastage or eliminating unnecessary steps or operations, and is expressed in the units of energy saved. Examples of conservation measures include turning off lights in vacant rooms, using night setback thermostats and shortening the preheat time on an oven or furnace. Conservation is often achieved by simply modifying the methodology or scheduling of operations and can achieve tangible savings with minimal investment costs.

The term “energy conservation” continues to carry negative connotations derived from early attempts, which sometimes included “doing without.” Recent conservation methods offer the same or better results while using less energy.

Energy efficiency refers to more effective use of fuel or energy; the process or environment maintains the level of production with similar or improved quality while using less energy. Energy efficiency typically requires capital expenditures and focuses on technology to achieve better use of energy. Efficiency requires a baseline for comparison purposes, which can be a step in the process or operation “as found,” or a benchmarked facility or process. Energy efficiency is typically expressed as a percentage of the quantity of energy actually utilized. This percentage gain is applicable only to the energy throughput of the equipment affected. Examples of efficiency measures are replacing unit heaters with infrared systems, upgrading the burner in a boiler or preheating combustion air for a furnace.

For the purposes of this Guide, efficiency and conservation measures or improvements will not be noted independently but will simply be referred to as “energy efficiency.”

Energy management is a continuous improvement plan for incorporating both of these components into a business and its operations. It can be defined as the judicious use of energy to accomplish pre-described objectives. Most importantly, good energy management practices must not reduce the effectiveness of production or the quality of the product.

Good energy management practices also benefit the environment. Lower energy consumption reduces the amount of pollutants and emissions released into the soil, atmosphere and bodies of water. Corporations should capitalize on all the credit and positive public relations from implementing energy efficiency measures. In some areas, environmental benefits can offset the costs associated with efficiency measures. Where corporate strategies allow, contact local utilities and government agencies prior to implementing measures to enquire about the availability of assistance programs. A list of sources of assistance and information is included in the Appendix (page 50).

Most efficiency and conservation programs consider all types of utilities, including all energy sources, purchased or processed water and sewer usage. Secondary utilities, such as compressed air or steam produced on site, are also included.

Because purchased energy represents the majority of total utility costs, the term “energy” will be used. The term “utility” or “utilities” will be reserved to identify the supplier of utilities or local distribution company.

Lastly, this Guide has not attempted to list all potential areas of savings but suggests items most directly applicable to the lime industry. For example, since there are very few opportunities to utilize low-grade heat, there are no suggestions for researching or implementing heat recovery from air compressors and motors.

1.3 ENVIRONMENTAL VALUE

Energy efficiency measures have a direct impact on emissions and the environment. With public attention on the Rio and Kyoto summits that tabled aggressive targets for reductions in energy-related emissions, all actions should be registered, regardless of the level of energy savings.

Canada’s Climate Change Voluntary Challenge and Registry Inc. (VCR Inc.) publicly documents individual company commitments and progress toward emissions reductions. VCR Inc. was developed, in part, to give companies credit for early and voluntary actions. It is anticipated that this documentation process will ensure that registered companies can retroactively claim their efforts should emissions trading become a full-scale reality.

At the time this Guide was prepared, six of the eight member companies in the Canadian Lime Institute (CLI) had registered and submitted plans to VCR Inc., representing 75% of the membership and approximately 57% of CLI's annual rated capacity.

A program overview and the corporate benefits of being involved in VCR Inc. is available through the VCR Inc. contact listed in the Appendix (see page 54).

1.4 UTILITY AND GOVERNMENT ASSISTANCE

Most utilities have technical field representatives who can assist energy users with short-term measurement and provide some technical information to help make the decision to proceed with an energy efficiency project. The level of knowledge or support available varies with the utility's commitment to customer service. Before requesting site assistance, verify the costs or rates charged for the desired services.

Many local utilities have mandates to work with their customers to ensure that the energy they supply is used in the most efficient fashion. Demand side management (DSM) programs have been developed to supply market assistance to implement energy efficiency measures, with the goal of transforming the market to readily accept higher efficiency alternatives. There are three primary types of assistance: education, higher efficiency product marketing and technical assistance. Some utilities continue to offer financial project assistance through incentives and grants.

Utilities that are involved with DSM programs report energy savings that result from their "influence" to their regulating bodies. To be eligible for financial assistance, potential projects must be qualified prior to implementation. Currently, the customer, not the utility, claims emissions reductions and associated credits. Ensure that this is true for the utility in question before receiving any financial grants or incentives.

A substantial push for increased energy efficiency in the industrial sectors occurred in the 1980s. Utilities and governments alike invested substantial time and effort to help customers identify energy-saving opportunities, usually at little or no cost to the customer. Many of these reports were shelved before the recommendations had been fully investigated or implemented, partially because of low energy prices. Today, the focus is on the competitive advantage of increased energy efficiency. Facilities are encouraged to research their archives for suggestions and recommendations that have already been prepared and may now be feasible because of fuel cost or market changes (i.e. if the product value has increased, it might be viable to increase throughput with an energy-efficient device).

Although government programs change, the current push to reduce emissions has spurred a number of service and financial offerings. One of these is the supply of technical resources for new or leading-edge projects or programs. Through the ON-SITE program, a partnership between the Government of Canada and the Alliance of Manufacturers & Exporters Canada, unemployed professionals can be provided to industries at limited cost for projects in areas such as the following:

- occupational health and safety;
- solid-waste reduction and waste management;
- energy management; and
- quality and environmental management.

Contact details for ON-SITE programs are included in the Appendix (see page 54).

1.5 ENERGY EFFICIENCY ASSISTANCE

Expertise is available in the industrial marketplace to identify, support and implement energy efficiency measures for parties that lack sufficient staff or knowledge. Many energy service companies (ESCos) have built their businesses on identifying and implementing energy-related capital improvement projects. They can suggest innovative financing options and offer guaranteed savings on efficiency projects. Engineering firms and equipment manufacturers are also a good source of information on technology and market trends.

A common approach is to develop a relationship with a non-partisan service provider who can implement projects with the best interests of the company in mind, bringing in only those experts who add value to the proposed project. A good service provider will also deliver environmental value and utility assistance at the proper stages, and will request any provincial or federal government assistance that is available at the time of the project.

Some components of a certain process, operation or business approach may have been analysed or studied in the past. There are many excellent publications available to help identify and implement energy efficiency measures. A good starting point is the *Energy Efficiency Planning and Management Guide* from the Canadian Industry Program for Energy Conservation (CIPEC). The Appendix includes contact information to obtain this Guide (see page 54).

1.6 COMMITMENT TO ENERGY EFFICIENCY

A company needs input from all aspects of a business operation to successfully manage energy use (see Figure 1). Financial planners are required to outline acceptable economic parameters, plant managers and supervisors should understand the nuances of the facility's processes, and a project leader should ensure that all activities are channelled through the proper contacts. Finally, technical expertise should be available to implement the measures successfully.

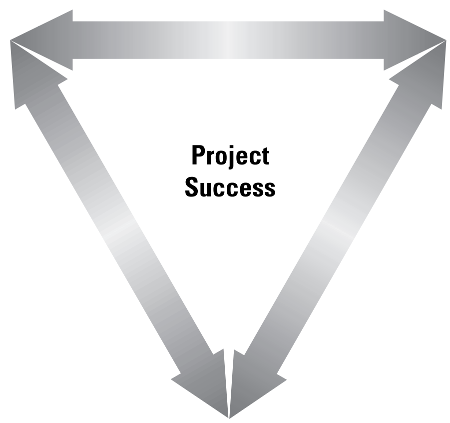


FIGURE 1.
Project Success Triangle

Often, barriers to energy efficiency projects must be overcome to realize savings. The following are some common barriers:

- lack of awareness of opportunities;
- lack of understanding on how to proceed;
- limited support from management;
- low priority accorded to energy or utilities;
- limited finances (competition for capital) or staff availability;
- limited internal accountability for measures; and
- perceived risk of changing from the status quo.

Energy efficiency projects should be implemented in a rational, logical fashion. Allow some time between projects to analyse the impacts of measures before implementing new ones. Overlapping projects may cause confusion, and fine-tuning each measure to receive optimum benefits becomes more difficult. If there are problems with a specific change, they will become evident more readily and can be modified without long-term effects.

When performing economic calculations for energy efficiency projects, ensure that taxation and capital cost depreciation are figured into total costs. In an effort to promote energy efficiency and greenhouse gas reductions, provincial and federal governments have structured tax laws and regulations to provide incentives and accelerated depreciation. Accountants can offer advice on how these regulations apply at the time of the project.

Often, the economics of replacing capital equipment are considered only at the end of the equipment's useful life. This practice almost always delays cost-effective projects and energy savings. Where projects are cost-effective within the definition of a specific operation, plan to perform the improvement or capital replacement as early as possible to realize savings sooner rather than later.

For example, replacing a failed conventional motor with a high-efficiency one may have a simple payback of six months, whereas replacing a newly installed conventional motor may have a simple payback of five years. If the threshold for implementing projects is a three-year payback, then a schedule could be implemented to replace conventional motors with high-efficiency ones as they reach a certain age and are at the necessary depreciation level.

In this Guide, simple payback measures are assumed to be calculated at the end of the equipment's useful life cycle, unless otherwise noted. This is to ensure that decisions to deviate from the base case take individual financial considerations into account.

2.1 INTRODUCTION TO THE LIME INDUSTRY

Limestone is an inorganic mineral found in abundance all over the world. In its natural form, it is often strip mined in a conventional manner, crushed and processed according to the desired end-use. Some stone is prepared and sold for decorative or structural aggregate, and the remainder is processed for industrial, chemical or environmental applications. The primary Standard Industrial Classification (SIC) Code applicable to such producers is 3581.

Two basic types of lime are produced: those with a high calcium content, termed "high calcium" (CaO), and those with a high magnesium and calcium content, termed "dolomitic lime" (MgO.CaO). High-calcium limes, by definition, must contain less than 5% magnesium.

Both types of limestone have a high carbonate (CO_3) content, which dissociates CO_2 at temperatures of approximately 725°C and 900°C (1337°F and 1652°F), depending on the stone's chemistry. It is this dissociation or calcining process that transforms the limestone into the desired active lime product. Although physically similar in size before and after the calcining process, the end product is 44–47% lighter than the original stone. It should be noted that chemical grade, high-calcium quicklime is less than 100% calcium oxide.

Following are some of the more common applications for lime.

METALLURGICAL USES

- iron and steel
- aluminum and bauxite

INDUSTRIAL AND CHEMICAL USES

- pulp and paper
- sugar refining
- glass

ENVIRONMENTAL USES

- water treatment
- sewage treatment
- flue-gas de-sulfurization

CONSTRUCTION USES

- soil stabilization
- lime for building and construction

REFRACTORY USES

A breakdown of sales by major application is shown in Table 1.

TABLE 1. Merchant Lime Applications, 1996

MAJOR APPLICATION	PERCENTAGE OF SALES (APPROX.)
Steel making	50
Environmental control	14
Pulp and paper	14
Chemical production	8
Other industrial uses	14

Source: *Minerals and Metals: Preliminary Analysis of Actions and Opportunities for GHG Mitigation*. Minerals and Metals Working Group – Industry Issues Table (CIPEC), July 1999.

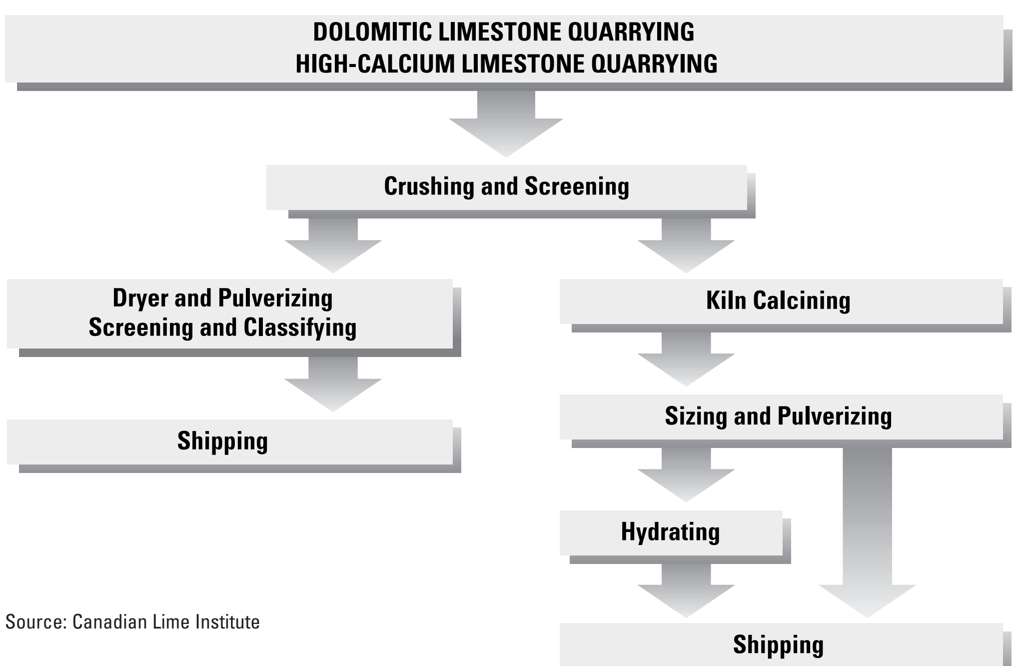
It is important to distinguish between the two processing streams for lime. Merchant lime, as identified in the table above, is typically processed directly at the quarry (or nearby) and is marketed and sold in specific forms for end-user applications. Lime is less expensive to transport than the heavier, unprocessed limestone.

The second major processing stream is through integrated lime producers who process limestone to satisfy their internal production requirements. This integrated process is common in the steel, sugar, and pulp and paper industries.

This Guide focuses primarily on merchant lime facilities (identified by SIC 3581). Many ideas and tips presented here, however, are also applicable to integrated lime producers.

Figure 2 shows the typical lime processing path.

FIGURE 2. Lime Processing Schematic



Source: Canadian Lime Institute

2.2 ENERGY USE AND BREAKDOWN

Energy costs account for approximately 40% of the total production cost of lime. Most of this energy (in the form of natural gas, petroleum coke, coal and heavy oils) is consumed in kilns during the calcining process. Fuels are selected according to their availability and their impact on product quality and cost. Changes in maintenance schedules and costs also come into play in the overall selection of fuel.

Less costly fuels often require more energy to prepare and burn. These parameters must be fully understood when selecting the fuel type, preparing costs or calculating efficiencies. For example, coal and coal derivatives may require the use of a heated milling operation for which the cost of the fuel used in the preheat, the mill drive and the fuel transportation pumps and fans must be included in the total energy analysis. The impact that the fuel has on the quality of the lime directly affects the value and size of the market for the product, and should be included in the fuel cost analysis.

In comparison, natural gas requires no ancillary equipment and therefore the burnertip cost can be considered to be the total cost. This is not to imply that natural gas is a less expensive fuel to use, but it does require less energy to prepare and burn it. Furthermore, the burnertip fuel cost may be affected by its efficiency in the kiln. The lower radiant capabilities of natural gas decrease the efficiency in the kiln relative to coke or coal.

Based on 1996 figures, the total energy consumed in the merchant lime industry is 14.6 million gigajoules.[1] Ratios of fuel types used are shown in Figure 3.

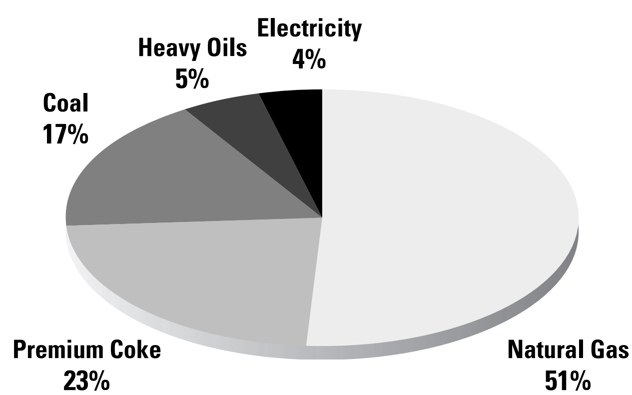


FIGURE 3.
Energy Consumption by Fuel Type

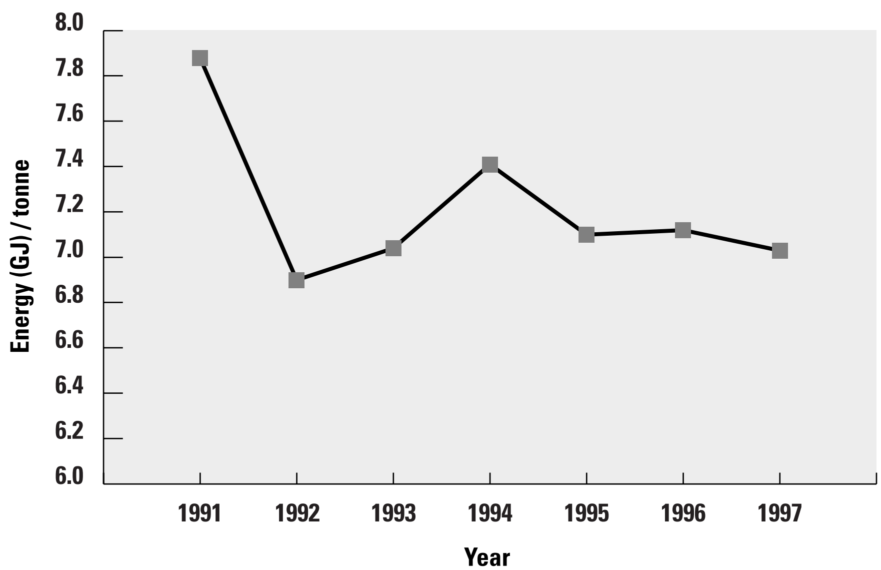
[1] Mineral and Metals Working Group of the Industry Issues Table: *Minerals and Metals Foundation Paper,* March 1999 (available at http://www.nccp.ca/html/index.htm, "Issue Tables" and "Industry").

Every lime facility should have an accurate and up-to-date analysis of kiln fuel efficiencies and fuel system costs to be prepared to take advantage of total fuel cost differentials. Good analysis is a critical component of selecting the proper size and design for fuel systems.

The ratio of energy consumption to unit lime outputs represents the energy intensity indicator and reflects changes in efficiency. The indicator varies from year to year based on production levels, equipment changes and overall market pressures. Figure 4 sets out the energy intensity trend in the lime industry as identified by SIC 3581. The trend is toward decreasing energy intensity (energy consumption per product throughput) over the seven-year period starting in 1990.[1]

According to CIPEC figures, the lime industry shows more progress on intensity reductions than Canadian industry as a whole, which has posted a slight overall decrease in intensity.[2] This could be attributed, in part, to better utilization of the higher efficiency kilns installed during the energy conservation movement of the 1970s and 1980s. It may also be the result of the innovation of equipment manufacturers, who have developed more energy-efficient equipment to maintain their market share and assist lime producers in lowering operating costs.

FIGURE 4.
Energy Intensity Indicator: Merchant Lime Facilities



[1] Canadian Industrial End-Use Data and Analysis Centre, *Energy Intensity Indicators for Canadian Industry 1990 to 1997.*
[2] CIPEC 1996/1997 Annual Report

2.3 OVERALL KILN DESIGN

The age, type and specific design of a kiln affects its overall efficiency. As set out in Table 2, the efficiency of different units may range from 4.0 gigajoules per tonne (GJ/tonne) to 13 GJ/tonne,[1] with a current accepted industry average of 6.6 GJ/tonne.[2]

All kiln replacements fall outside the scope of this Guide because the simple payback based on energy savings alone is well beyond the three-year point. However, market pressures, changes in product demand or consolidation of processes, combined with fuel savings, may make total kiln replacement feasible.

The kiln fuel efficiency analysis discussed in the preceding section provides part of the baseline for decisions on consolidation of process lines, with the understanding that product quality must not be sacrificed. Whenever possible, the most efficient kiln should be operated the maximum number of hours, with less efficient kilns brought on only as necessary. Increased throughput in the most efficient kiln will make other efficiency upgrades, such as improved preheaters or refractory materials, more cost-effective.

Because of variations in chemical and physical properties of the limestone – as well as in fuel supply, burner design, kiln design, required throughput and many other factors – it is nearly impossible to recommend cost-effective kiln replacements or major modifications for specific sites. However, some basic guides have been included in Section 5.0. Overall kiln efficiencies based on design style are included in Table 2.

TABLE 2.
Kiln Efficiencies Based on Design Category

DESIGN OF KILN	EFFICIENCY RANGE IN GJ/TONNE	ESTIMATED PRODUCTION BY KILN TYPE
Long rotary kilns (typically with no preheat)	**7.0–13.0**	**30%**
Rotary hearth kilns (calcimatic)	**6.0–9.0**	**5%**
Short rotary kilns (typically with preheaters)	**5.5–8.0**	**30%**
Shaft or vertical kilns	**5.0–7.0**	**20%**
Double shaft or annular shaft kilns	**4.0–4.5**	**15%**

Source: Mineral and Metals Working Group of the Industry Issues Table: *Minerals and Metals Foundation Paper*, March 1999 (available at http://www.nccp.ca/html/tables/industry.htm).

[1] Mineral and Metals Working Group of the Industry Issues Table: *Minerals and Metals Foundation Paper*, March 1999 (available at http://www.nccp.ca/html/tables/industry.htm).

[2] Minerals and Metals Working Group

3.1 NATURAL GAS

Natural gas costs have three primary components: transportation, distribution and commodity. The costs of these three variables can be modified or controlled to a degree. The current situation in the marketplace, in part caused by utility unbundling and deregulation, represents an opportunity for the informed consumer. End-users can now select services and options to meet the specific requirements of their facilities. It is important to ensure that natural gas is supplied at the appropriate rate, that pipeline or demand charges are mitigated, and that the proper program is in place to receive advantages from market fluctuations. Some areas to investigate include the following:

DISTRIBUTION

- ensure an appropriate rate based on usage profile;
- consolidate the number of meters to limit user charges;
- choose between interruptible or firm service based on ability to switch fuel sources;
- modify usage to gain preferential rate; and
- ensure that correct billing charges are applied.

TRANSPORTATION

- purchase transportation at the lowest cost according to risk profile;
- avoid or mitigate demand charges; and
- ensure that service contract is suitable to market conditions and load profile.

COMMODITY

- make a least-cost commodity purchase; and
- ensure that correct billing charges are applied.

The preceding list is not comprehensive, but it illustrates the point that simply purchasing the commodity at a “good” price does not ensure natural gas at the lowest cost. There are several natural gas agents that work with end-users to monitor the market and recommend strategies for cost-effective purchasing. Using an agent alleviates the time allocation and associated burden of natural gas purchases, especially given the volatile nature of natural gas commodity prices and frequent changes in tolls, tariffs and opportunities related to transportation and distribution.

3.2 ELECTRICITY

Electricity deregulation and utility unbundling are considered to be positive steps toward encouraging a competitive marketplace – utilities will no longer have a complete monopoly on all aspects of electricity generation, transmission and supply services. Canada's provinces have advanced toward deregulation on varying timetables, which means that opportunities will differ depending on location.

For example, in Ontario, the electricity sector offers flexibility in purchasing and some control over transmission, services and distribution costs. Consumers that have a clear understanding of how electricity is consumed at their facilities will have the best potential for saving money in this new market.

Markets for electricity are much more complex than natural gas markets; the following discussion is intended to illustrate only a sample of the areas that should be investigated. There are two basic electricity rate structures, designed primarily to recover the costs of power generation and infrastructure in different market sectors. They are the time-of-use rate and the general service rate.

Time-of-use rates are designed to recover costs incurred by the utilities for generation of electricity at specific times. These rates are forecasted based on the anticipated costs to generate power at certain times. During daytime and evening hours (typically 7:00 a.m. to 11:00 p.m.), there is high overall demand and "peaking" generation is usually more costly to operate. Costs are passed back to the customers who consumed the incremental power.

In British Columbia, a variation on the time-of-use theme is called real-time pricing. Real-time pricing rates ensure that customer charges are based on the actual costs at the power pool, rather than on forecast costs.

Time-of-use and real-time pricing rates represent excellent cost-saving opportunities for facilities that can shift energy requirements to off-peak periods.

General service rate contracts allow customers to use electricity at any time of the day without penalties or benefits. The electricity charges are calculated in "blocks" – as the number of blocks used increases, the unit cost of the electricity decreases. Savings are tied directly to reducing actual consumption. The day and night peak charges are averaged to cover the costs associated with power generation and supply. There are also seasonal changes in price from summer to winter, but these are of little consequence to the lime industry as most plants operate year-round.

Most rates incorporate a demand charge element. Peak or maximum demand is usually in the form of a "spike" or high load for a short period, which sets the demand charge rate for the billing period. Reducing this demand peak will not necessarily reduce energy consumption, but it will lower electricity costs. A potential area for demand savings in a quarry is in the de-watering pumps, which should be operated in off-peak hours in conjunction with a water level indicator.

Other costs or cost reductions are applied to the basic rate schedules according to services and equipment supplied, such as transformer charges or credits, additional transmission charges, backup power charges, interruptible discounts and high-voltage discounts. It is suggested that all Canadian lime producers thoroughly investigate the rationale for all charges incurred to ensure that they have contracted with the electricity supplier at the appropriate and most cost-effective rate.

A cost-of-service analysis can be performed to estimate the profit margin a utility earns by serving a specific lime facility. This analysis can ensure that cross-subsidization of other customers or customer classes is minimized. A company can achieve cost savings by negotiating with the utility if a specific facility is found to be less costly for the utility to service than the tariff cost, which is based on an average customer.

The power factor charge is another cost that can be modified and manipulated. Power factor defines the relationship between active power and apparent power and is, in fact, a measure of how effectively current and voltage are converted into useful electric power.

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

Utilities can either charge customers a fee for having low power factors or they can supply a rebate to those with high power factors. Although this is primarily a cost issue, there is a small efficiency gain through reducing resistive line losses. A low power factor can be improved with properly sized transformers, AC induction motors and heating coils, or by adding capacitor banks.

Lime producers responsible for their own transformers might consider acquiring new higher-efficiency models that reduce the overall kVA load through reducing internal losses. When a process or line is shut down or there is no load on a specific transformer, disconnecting the primary side of that transformer will avoid utilizing the energizing current that is consumed, even when there is no secondary power draw.

A good Web site for support information on transformers can be found at www.copper.org.

The following are some ways to boost electrical cost savings:

- ensure that the contract allows for most beneficial rate structure;
- negotiate custom rates as the utility will allow;
- reduce the facility's peak demand;

- correct power factor billing penalties;
- ensure that all incurred costs are at the proper level for services received; and
- prepare a cost-of-service analysis.

Municipal and provincial electrical utilities will often assist customers with temporary metering to provide a clearer picture of energy use. Their services may also include advice on reducing consumption and demand charges, and increasing power factors.

A monitoring and targeting system (see Section 4.1) will provide the information required to purchase energy intelligently by clearly showing how and when energy is used in a facility.

3.3 NON-UTILITY ENERGY

Non-utility energy – such as coal, coke, propane, gasoline, diesel fuel and oil – is more difficult to deal with in general terms. The price and availability of these sources depend heavily on the region of use, competition between suppliers and general supply and demand. Since prices are basically market-driven with little or no regulatory intervention, companies are better able to negotiate contracts and rates with suppliers, as they might for the commodity portion of natural gas.

Price and terms of delivery are tied to the risk profile of the end-user and will be decided in conjunction with the preparation of a fuel cost study as set out in Section 2.2, "Energy Use and Breakdown."

3.4 PURCHASED WATER

Conservation of all natural resources, including water, is of concern to all Canadians. Use of purchased or processed water within the lime industry is very small and is a negligible component of total utility costs and consumption. Most water-related costs occur as a result of de-watering and not from the purchase of the commodity or maintenance of a well. Purchased or processed water is therefore not discussed in any detail in this Guide.

The hot water supply represents a very minor water-related energy cost. Mid- to high-efficiency hot water tanks can be purchased or rented for savings in high-usage areas such as showers. Simple payback of this measure will be directly related to the level of consumption but should be less than three years. This measure can be made even more cost-effective by installing water conservation shower heads and properly sizing the water tank. Insulation blankets on older hot water tanks reduce heat loss.

4.1 MONITORING AND TARGETING

Monitoring and targeting (M&T) is a methodology used to quantify energy use, allowing for improvements to be made based on actual data rather than assumed values. M&T can be broken down into two stages: understanding in detail how energy is currently being used and then identifying and implementing changes designed to reduce usage. M&T provides a disciplined and structured approach to ensure that all energy sources (gas, oil, electric, water, propane, etc.), primary and secondary, are utilized to full potential.

Monitoring and targeting provides the baseline measurement of how much, how quickly and where and when energy is consumed in a facility. This information is critical to the success of energy efficiency projects, as it identifies where the most effective improvements should occur and what their subsequent impact on utility consumption and cost will be.

Many facilities already have a substantial monitoring system in place and may need only to refine it to supply the information required for targeting.

Targeting is the interpretation of accurate data and the resulting identification of detailed solutions. The systems used in targeting should generate reports automatically to limit the amount of operator time required.

Targeting is more specialized energy management work and requires an in-depth understanding of energy applications. It is considered a continuous improvement strategy and does not necessarily require capital resources for equipment replacement. Targeting includes the application of information gained through the monitoring or energy management system (EMS).

M&T allows the user to identify, understand and track the effect of many of the energy efficiency measures suggested throughout this Guide; it should be considered part of the process of developing a total energy management program.

A properly designed M&T system ensures that every point measured supplies critical data and has the ability to recover the cost of the meter and associated hardware. This system should take advantage of existing metering equipment wherever possible. M&T systems have a direct tie into ISO 14000 programs and can increase the ongoing value received from investment in a quality system. There is also a benefit to the corporate mindset, as changes are accepted and implemented much more readily if it is easy to see the difference that has been made.

M&T systems can be implemented in a rather short time (six months) and some savings can be realized almost immediately as a result of measurement of suspect areas of the process. Identifying larger savings opportunities may take longer, as the collection of baseline data required to understand and identify problem areas may take several years, especially for seasonally related issues.

Total energy savings depend on knowledge of energy consumption patterns (when, where and how much). Energy savings are also linked to availability of higher efficiency equipment, over and above what is currently being used. An M&T system is one of the best ways to identify, promote and track cost-effective operational and equipment improvements.

Simple payback of this measure is shown in the table in Section 5.2, "General Methodologies."

4.2 ENERGY ACCOUNTING

Energy accounting is directly related to the ability to monitor and meter energy use. Where suitable business units or differentiation in department responsibilities exist, energy accounting uses monthly billing and internal reporting to tie energy consumption to individual budgets or profit centres.

This accountability supports energy efficiency through increased awareness of the link between cause and effect. It ties the cost of energy and the impact of its use directly to those who have the greatest ability to affect them. Managing costs at this level helps to increase departmental responsibility and encourages users to develop their own efficiency methodologies.

Breaking energy consumption down into smaller components also allows goals to be set at more realistic, manageable and tangible levels than a corporate-wide initiative allows. Although targets can be derived from measured data, they must be realistic and agreed upon by those responsible for delivering the savings. Energy accounting is part of a continuous improvement strategy.

Simple payback of this measure is shown in the table in Section 5.2, "General Methodologies."

4.3 EMPLOYEE AWARENESS AND TRAINING PROGRAMS

As with energy management systems, training and awareness can lead to energy reductions and process improvements. The goal should be to train staff, in terms of both skills and approach, to include energy efficiency in day-to-day practices resulting in small but continuous improvements. It is also possible that excellent energy-efficient products, services or opportunities have already been identified by staff members but have not been promoted because of perceived or real barriers such as those listed in Section 1.6.

An effective awareness and training program starts with senior management's commitment to energy savings, support of the projects and encouragement throughout the organization. Wherever possible, management should remove barriers, encourage open discussion and promote ideas that improve efficiency. Re-evaluate suggestions and opportunities as markets, energy costs and technologies change and evolve.

Several formal training and employee awareness programs are currently available, including those offered by Natural Resources Canada, the Canadian Institute for Energy Training and a variety of independent stakeholders through conferences and seminars.

Efficiency gains resulting from employee awareness and efficiency training are difficult to quantify; it is, however, safe to predict that other energy savings will be limited and short-lived without the commitment and support of staff members.

4.4 FACILITY MAINTENANCE

Maintenance is a crucial component of energy efficiency measures. Although the nature of lime itself presents maintenance challenges to the industry, more facilities are recognizing the value of good maintenance practices.

Each facility should evaluate existing practices and balance preventive and predictive maintenance with the costs associated with downtime and repairs. Downtime represents the hard costs associated with inadequate maintenance and is usually well tracked and managed. The soft costs of maintenance affect the overall efficiency of a process and the quantity of energy required. This is not to indicate that maintenance has been ignored or does not follow the manufacturers' recommendations, but that maintenance is relevant to the efficiency of equipment and the facility.

For example, operating an air compressor with an air filter that may have become plugged prematurely (i.e. before scheduled maintenance) decreases inlet manifold pressure. For each 1% decrease, there is a corresponding 1% decrease in operational efficiency. With improved maintenance practices, it may be possible to recover 5–7% of this energy by avoiding operation with plugged filters. The effect is similar with most filtered equipment such as quarry and fleet vehicles.

Good filter maintenance can also avoid excessive air inlet restrictions, which contribute to excessive oil consumption and premature turbocharger failures. Where possible, perform maintenance in peak-energy cost periods and run systems normally in lower-cost periods. Specific recommendations regarding process equipment are made in Sections 5.1 to 5.10.

The importance of proper sizing of new or replacement equipment is often overlooked. In the 1970s, it was common to design and build equipment that could accommodate substantially increased production or load levels. In many cases, the market or need has never increased and the equipment has spent its life operating at partial load, which is usually less efficient than at design capability. Understanding process and load requirements – and measuring and monitoring loads – ultimately leads to replacement equipment which is the proper size, without falling back on the status quo.

It is a well-known and documented principle that most equipment should be shut down when not in use to conserve energy. However, this is often neglected or forgotten in practice. Wherever possible, add automated controls or system interlocks to control equipment duty cycles. To reduce electricity costs, operate equipment in off-peak times to avoid added demand charges.

Improper lubrication can affect energy consumption at any industrial facility. Using synthetic lubricants in rollers, motors, gearboxes and reduction drives decreases friction and reduces associated labour and maintenance costs. Synthetic lubricants retain a more constant viscosity over wider temperature ranges, have higher lubricating qualities, resist oxidation better and last longer than petroleum lubricants. In fact, using higher quality products can increase lubrication intervals significantly. A recent study on energy conservation techniques shows that using synthetic lubricants can reduce energy consumption by 10–20%[1] (because of the frictional losses associated with single-grade petroleum lubrication). The increase in initial lubricant cost is offset by longer life expectancy.

When changing lubricants or lubricating intervals, it is necessary to consult with equipment manufacturers to ensure compatibility with the design and materials used. Also, lubricants must be handled carefully to ensure they are contaminant- and moisture-free.

[1] Brewers Association of Canada, Natural Resources Canada and the Canadian Industry Program for Energy Conservation (CIPEC): *Energy Efficiency Opportunities in the Canadian Brewing Industry*, Ottawa, 1998. Available at no cost from Natural Resources Canada's Office of Energy Efficiency; fax (613) 947-4121.

ENERGY EFFICIENCY TIPS
5.0

5.1 INTRODUCTION

This section suggests potential areas of savings as applicable to various processes or appliances within the lime industry. The tables found at the end of each topic give simple payback estimates for identified tips. Simple payback is defined as the total cost of a measure divided by the annual energy cost savings. The sample table below describes typical data presented within this document.

Sample Table

TYPE OF MEASURES	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Low or no investment	Resource, training or procedure	Six months or less	As applicable
Retrofit opportunities	Capital	Six months to three years	As applicable
Major retrofits	Capital	More than three years	As applicable

An attempt has been made to present tips related to generic measures and technologies before specific ones, because many of the general measures apply to several different areas. For example, in the case of electric motors, the initial tips given in the general section apply to almost all motorized appliances, such as conveyors, air compressors and crushers.

Where "each element" is stated in a table, this indicates that each of the measures in the section individually result in the simple payback specified and that all measures need not be implemented to supply the stated results.

5.2 GENERAL METHODOLOGIES

The following table supplies an economic measurement of the generic energy efficiency tips suggested in the first half of this document. Section numbers of this Guide have been listed in the comments column for easy reference to the relevant section.

TABLE 3.
General Methodologies

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Power factor correction	Resource, training, capital	Six months to three years	Section 3.2
Energy-efficient transformers	Capital	Six months to three years	Section 3.2
Disconnecting transformer primary when not in use	Resource	Six months or less	Section 3.2
Higher efficiency hot water tank	Capital or rental	Six months to three years	Section 3.4
Monitoring and targeting	Capital	Six months to three years	Section 4.1
Energy accounting	Resource	Six months or less	Section 4.2
Employee awareness	Training	Six months or less	Section 4.3
Facility maintenance	Resource	Six months or less	Section 4.4
Proper equipment sizing	Resource	Six months or less	Section 4.4

5.3 LIGHTING

Lighting is not a high priority at most lime facilities. There are, however, some relatively simple, low-capital opportunities to reduce electricity consumption. When improvements or upgrades are being done, each lighted area should be addressed to ascertain the correct wattage and number of fixtures for a given style of lamp. If an area is found to have excessive lighting levels, reduce the number of lighting fixtures in that area.

Lights need to be controlled to ensure that they are operated only when required. This can be done manually, through photocells or through the use of timers. Manual control is a low-cost measure, but is also the least conducive to energy efficiency and probably the least effective. Giving the responsibility for turning lights on and off to one person (say, an employee doing rounds) may help eliminate unnecessary daytime operation. A good employee training program will assist with this measure.

Using photocells to control the timing of lighting is a widely accepted practice and yields good savings, especially when combined with an override system for off-hours. However, if sunlight is blocked from the sensor (because of dust, dirt, airborne contaminants or shade), lights may remain on, so caution should be exercised.

Timers with manual overrides are the most effective technique for controlling lighting and can be programmed to turn on or off at various times, depending on need. This is also a more expensive retrofit because it requires integrating lighting circuits in each building or grounds area. However, timers should be installed as a matter of course for each new building, area design or building stage.

Lighting types should be the most efficient available for the purpose. Where there are low ceilings indoors, use fluorescent instead of incandescent lighting. For outdoor applications, use low-energy sodium lamps. Colour rendition is generally not an important quality for lighting in most areas of the lime industry.

Wherever possible, eliminate the use of portable light stands and generators. A portable generator converts only approximately 30% of the fuel energy into electricity; the rest of the fuel is rejected through the engine cooling system.

OVERALL LIGHTING STRATEGIES

- Use lights out of necessity, not out of routine. Encourage employees to shut off lights when not required.
- Use motion detectors in offices or where staff presence is intermittent.
- Use lighting timers instead of photocells on external lights and process building lights.
- Ensure that external lighting is the most efficient available for the application.

CAPITAL PROJECTS

- Replace incandescent and older fluorescent lamps with high-efficiency fluorescent lighting.
- Utilize high-efficiency magnetic ballasts (instead of electronic ballasts) for low-duty fluorescent lights and electronic ballasts for higher-duty lights.
- Replace external lighting with sodium lamps.
- In buildings with high ceilings, replace older fluorescent lights with sodium or metal halide lights.
- Install timer systems as appropriate.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Overall lighting strategies (each element)	Resource	Six months or less
Capital projects (each element)	Capital	Six months to three years

5.4 HEATING OF BUILDINGS

Lime processing facilities generally require a marginal amount of space heating; therefore, opportunities for energy reductions are limited. Approximately 10–15% of the total building heating costs can be recovered through the measures described below.

Most offices are heated with electricity or forced-air gas, oil or propane. Converting from electric to gas, oil or propane can offer cost advantages, depending on fuel availability and prices at each location. New or replacement furnaces should be mid- and high-efficiency, with automated setback controls. As in the home, ensure that windows and doors are closed promptly and that weatherstripping and seals are in good condition.

Workshop and repair areas are best heated with tube-type low-intensity infrared heaters. They are more efficient and will be less affected by difficult conditions than conventional unit heaters. They are also more durable than high-intensity infrared heaters, which have the additional drawback of emitting water from the products of combustion into the working environment. New ambient and radiant sensing thermostats can assist in avoiding overheating and ensuring temperature setback in periods without occupancy, resulting in up to 15% energy efficiency gain.

OPERATIONAL PROCEDURES

- Where possible, heat only critical equipment storage areas.
- Install and use setback thermostats.
- Update weatherstripping and seals in all heated areas.
- Shut off ventilation in off-peak periods.

CAPITAL IMPROVEMENTS

- Install high-efficiency furnaces.
- Update the building envelope to minimize air infiltration in maintenance shops and offices.
- In shops, use low-intensity infrared heaters along with radiant thermostats.
- Convert to less expensive fuel.
- Install rapid door closers in high-traffic areas.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
High-efficiency furnace replacement	Capital	More than three years
Low-intensity infrared replacement	Capital	More than three years
Replacement at end of service life	Maintenance	Six months or less
Infrared thermostat	Capital	Six months or less

5.5 AIR COMPRESSOR SYSTEMS

Compressed air is used in the lime industry for control systems, cleaning purposes and fluidization of fines. The consumption or waste of compressed air is often overlooked. Compressed air is an inherently inefficient medium as an estimated 85% of the original energy consumed by the compressor is directly converted to heat.

Air compressor use and load may not be a prime consideration. However, significant gains are available through equipment replacement and modified maintenance and operational procedures. Most newer equipment incorporates efficiency practices and controls into the initial design or system package.

MAINTENANCE/DESIGN

- Replace filters based on pressure drop.
- Duct the fresh air inlet outdoors to provide the coolest air possible.
- Ensure proper compressor pump cooling.
- Identify and eliminate compressed air leakage.
- Eliminate unused branches of air piping system.
- Run the system at the lowest practical air pressure.
- Duct discharged cooling air outdoors in the summer and into the building for additional heating in the winter.
- Implement leak detection and repair procedures.

OPERATIONAL MEASURES

- Where possible, use air based on actual requirements, not a timed schedule.
- Shut off all air-consuming equipment and compressors when not in use.
- Review applications and make changes to ensure that compressed air is used only in effective applications.
- Eliminate air controls that utilize air bleeds to the atmosphere.

CAPITAL PROJECTS

Ordinarily, older inefficient compressors should be replaced with updated efficient models. These models feature advances in the operational parameters, including variable speed drives and full-load/no-load operating techniques. Most manufacturers offer conventional and high-efficiency products for energy efficiency. Heavy-duty systems are also available to ensure the optimum operation even under less than desirable conditions.

The overall system should be designed to suit the specific site. Undersized filtration systems or poorly designed header or distribution systems can cause pressure drops with corresponding efficiency losses.

CAPITAL PROJECTS

- Consider retrofitting existing air compressors with variable speed electronics and drives.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Maintenance/design (each element)	Resource	Six months or less	—
Timing and use (each element)	Resource	Six months or less	—
Standard replacement	Capital	More than three years	Lowered payback with heat recovery
High-efficiency replacement	Capital	More than three years	Lowered payback with heat recovery
Variable frequency drive retrofit	Capital	More than three years	Very dependent on type of load

5.6 ELECTRIC MOTORS

A purchasing standard should be adopted to ensure that all newly acquired motors fall into the high-efficiency category. This is currently under way in most facilities where motors are being replaced as required. Some older motors should be replaced through an updating maintenance schedule, even if they have not yet shown signs of failure.

Standards for high-efficiency motors start at approximately 80% ratings for smaller motors and increase to approximately 95% for larger motors (more than 500 horsepower). As a rule of thumb, purchase motors with efficiency ratings of 90% or higher.

However, efficiency ratings are mostly irrelevant if a motor is operating at less than approximately 75% of its rated capacity. The tendency to oversize motors contradicts attempts to become more energy efficient. Therefore, when replacing motors, ensure that the specifications meet the application requirements (including a reasonable safety factor) rather than resort to "nameplate replacement" of the old motor. This advice applies to all motors on-site that have regular duty cycles, including pumps, fans and drives.

Excellent reference information regarding motor efficiency and design is available through the Copper Development Association's Web site at www.copper.org.

All motor drive systems have inherent inefficiencies due to frictional losses. Standard V-belts tend to stretch, slip, bend and compress, which leads to a loss of efficiency. Under well-maintained conditions, a V-belt will run at approximately 92% efficiency. Replacing these belts with cog-style belts can result in savings of approximately 2%, and upgrading to high-torque belts can result in up to 6% additional savings over the base case. Cog-style belts also require less maintenance and have a substantially longer life expectancy.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
High-efficiency motors	Capital	Six months to three years	Payback usually closer to six months
Belt upgrades	Capital	Six months to three years	—

5.7 VARIABLE FREQUENCY DRIVES

When a process is required to change its loading or throughput, a control measure must be developed. There are two primary ways to control throughput: flow control and speed control.

A flow control system typically operates at a constant drive speed but varies the output through "throttling" the flow with the use of inlet or outlet dampers, inlet or outlet valves or flow-bypass systems. A damper or valve system typically provides a lower cost alternative at first, but offers slight, if any, energy efficiency during partial load operation. A bypass design directs a portion of the output flow back to the inlet of the pump, thereby reducing the usable output of a fan or pump.

Adjusting the speed of an operation through the use of a variable speed pulley system also allows process flow control. This process provides some energy savings but may have an adverse effect on the facility's power factor due to the reduction of motor loads. Whenever changing drive speeds, it is critical to ensure that the efficiency of the driven equipment is not adversely affected, i.e. that slowing down a fan does not decrease the efficiency of the fan.

A variable frequency drive (VFD) changes the speed of a motor by changing the voltage and frequency of the electricity supplied to it, based on the system or load requirements. Properly engineered and controlled, a VFD will provide a wide variation in motor shaft speeds while offering substantial energy efficiency during lower speed or partial load operations.

The amount of energy savings achieved through the use of VFDs depends on the application. Savings are related to both the length of time a system operates at less than full load and the actual load factor. Table 4 compares the electricity consumption of a centrifugal combustion air fan (50 horsepower indicated on the nameplate, approximately 37 kW) with inlet dampers versus a VFD. The more speed or horsepower variation in the load, the more savings there will be to achieve.

TABLE 4. Example of Variable Frequency Drive Savings

OPERATING HOURS AT LOAD[1]	PERCENT OF FULL LOAD POWER	MOTOR LOAD (kW) WITH INLET DAMPER	MOTOR LOAD (kW) WITH VFD	KILOWATT SAVINGS	KILOWATT-HOUR SAVINGS
1,000	100	37	37	0	0
1,000	105	40	30	10	10,000
1,000	95	35	20	15	15,000
1,000	90	33	10	23	23,000

Source: Wayne C. Turner. *Energy Management Handbook* (third edition), Fairmont Press, Lilburn, Georgia, 1997, ISBN 0-13-728098-X.

1) Scaled to equivalent values of 1,000 for savings comparisons.

5.8 QUARRY VEHICLES

Diesel fuel used in quarry vehicles accounts for a small percentage of the total fuel consumed within the lime industry. Tracking use by vehicle can identify efficient versus inefficient equipment and can assist in quantifying impacts. This information can then be equated to equipment design, age, application or maintenance. Most of the recommendations apply to smaller fleet vehicles with an emphasis on selecting the most appropriate vehicle for the intended use.

The idling time of all vehicles should be reduced as much as possible. Ratings of engines vary, but a typical diesel highway vehicle engine can consume 2.5 litres of fuel per hour of idling. Reducing idling by half an hour per day over an average work year represents approximately 375 litres of fuel savings. The Toronto City Council has passed a by-law to limit idling to no more than three minutes in a given 60-minute period to reduce the environmental impact of unnecessary vehicle operation. It was found that shutting off and restarting an engine within three minutes was cost-effective.

Some sites have also gained efficiency through face-crushing the limestone and then transporting it by conveyor rather than trucking the stone to a crusher located at the processing plant. These gains may be site-specific.

Air filter maintenance and associated efficiency gains, as discussed in Section 4.4, “Facility Maintenance,” are applicable to all quarry vehicles.

OPERATIONAL MEASURES

- Log fuel use by vehicle (on-board computers on newer vehicles offer this feature).
- Where possible, shift efficient vehicles to higher duty cycles and less efficient ones to lower duty cycles (select the most appropriate vehicle for the task).
- Avoid idling for more than three minutes.
- Reduce spillage during filling, and fill only 95% of the tank to allow for expansion.
- Operate the vehicle in the most economic fuel range; if necessary, reset the governors.
- Use synthetic lubricants as applicable.
- Correct air filter maintenance (approximately 1% efficiency loss for each 1% decrease of inlet air pressure).

CAPITAL PROJECTS

- Where appropriate, combine the load of many small vehicles into fewer larger ones. Evaluate use and select the appropriate vehicle.

- Consider selecting higher-efficiency engines in new vehicles.
- Evaluate opportunities to face-crush and convey stone rather than trucking to the facility crusher.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Appropriate maintenance	Resource	Six months or less	—
Operational practices	Resource or training	Six months or less	—
Old vehicle replacement	Capital	More than three years	Productivity increase
Replacement with higher-efficiency vehicle over conventional vehicle	Capital	More than three years	—

5.9 PUMPING

Although the total quantity of fluid (gas, oil, water, etc.) pumping may be minimal and confined to a few small areas, lime plants and quarries can still take advantage of additional energy savings through process or operational changes.

Pumps are most often used for de-watering the quarry floor. This water accumulates in the bottom of the quarry by inflow and precipitation. Grading and ditch modifications performed above the quarry may prevent surface water, or run-off, from entering the quarry. Ensuring that water does not naturally flow toward the pit or seep back in from ditches or ponds can reduce the amount of water that cycles in and out of the quarry and thus reduce the de-watering pumps' load or duration of operation.

To increase overall pump efficiency, optimize the water collection areas within the quarry so that fewer larger pumps, rather than numerous smaller ones, are required. A larger water collection area will also allow pumps to be run intermittently and during off-peak electricity periods. These pumps should be controlled by timers (set for off-peak) with overriding level indicators to ensure that minimum and maximum water levels have priority over the time of operation.

Continuous pumping applications or high-duty pumping loads (such as lubrication pumps, hydraulic pumps and fuel supply pumps) can benefit from newer, high-efficiency pumps, which employ impeller and bearing designs to use less energy at a given flow rate. Higher efficiency de-watering pumps, on the other hand, can only be beneficial if they can be operated a large percentage of the time (high-duty cycle).

The previous sections on high-efficiency motors and variable frequency drives also apply to all pump and fan applications.

OPERATIONAL MEASURES

- Reduce water inflow into the quarry.
- Optimize water collection areas to allow stockpiling or ponding and enable off-peak pumping.
- De-watering should be performed during off-peak periods instead of when levels warrant.
- In all pump operations, limit bypass flow control as much as possible.

CAPITAL PROJECTS

- High-efficiency motors
- Consolidation of pumps
- High-duty, high-efficiency pumps
- Low-duty, high-efficiency pumps

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Operational measures (each element)	Resource	Six months or less	—
Optimized de-watering	Resource	Six months or less	—
Capital projects (each element)	Capital	Six months to three years	Except low-duty pumps
High-efficiency water pumps (low duty)	Capital	More than three years	—

5.10 FANS

Many fans are required for different purposes in the calcining process – introducing combustion air, supplying draft, transporting or increasing the velocity of the fuel supply, providing product cooling, adding exhaust dilution and providing exhaust gas recirculation, among others. Most fans operate on high-duty cycles and are shut down only when the kiln is down and cooled off.

Higher duty, high-load fans greatly benefit from newer impeller designs. These higher efficiency designs could save approximately $6,000 per year in reduced electrical consumption per 100 horsepower of fan drive. Updating impeller design can also increase fan capacity cost-effectively. These fans should be on a predictive maintenance schedule to identify wear and damage before long-term damage or energy losses occur.

Backward-inclined or backward-curve impellers appear to provide similar benefits to airfoil designs while offering a lower initial cost and an increased ability to handle dust-laden flue gases. All of these designs show improved efficiency over straight vane units.

Wherever possible, reduce the contaminant level in the air streams at the front of the fan itself to reduce efficiency losses and imbalances caused by buildup. This also helps lower the maintenance requirements and the risk of premature fan failure.

Reducing dilution-air requirements, as appropriate to specific applications, will reduce energy consumption by the affected fan. For example, utilize midstream lime cooler air for fuel grinding or preparation mills rather than diluting higher temperature air back to an acceptable temperature. Discussions in Section 7.0, "Kiln-Related Tips," provide another example of a method to reduce dilution-air fan loads through the use of evaporative cooling in the kiln exhaust.

OPERATIONAL MEASURES

- Stagger the start-up of fans during system start-up to avoid establishing a new higher demand and associated higher demand charges.
- Take advantage of opportunities to analyse actual load requirements and size fans and motors accordingly.
- Avoid throttling wherever possible.
- Perform routine fan diagnostics and maintenance (static pressure, RPM, lubrication, bearing and mount condition, and drive alignment).
- Perform routine damper adjustments and cleaning where applicable.
- Clean ducts and remove buildup (especially flue gas recirculation).
- Minimize dilution air.

CAPITAL PROJECTS

- Use high-efficiency motor replacements or re-manufacturing techniques.
- Use variable speed drives.
- Employ high-efficiency impeller design.
- Improve fan control of processes and minimize fan loads by eliminating air leakage in the kiln systems.
- Reduce dilution-air requirements through equipment changes.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Operational measures (each element)	Resource, training, procedure	Less than six months	—
Capital projects (each element)	Capital	Six months to three years	Except equipment changes
Equipment changes to reduce dilution air	Capital	More than three years	—

6.1 PROCESS FLOW, HANDLING AND PRODUCT QUALITY

Excessive product handling creates two basic problems: more energy is consumed handling the product, and the product loses some quality through the increased levels of fines.

Reducing the motor hours used for elevating and conveying limestone and lime results in direct energy savings. If a bypass is required due to a differential in feed rates, investigate the use of a variable speed drive on one of the mechanisms. Wherever possible, handle or move the product as little as possible.

Related to product handling, accurate weighing of the product will encourage good business decisions. This is not a direct energy measure but may affect the operators' ability to understand or compare process settings. For instance, if two identical kilns operating at the same fuelling rate and product type seem to be producing different quantities of product, it would appear that one kiln is more efficient than the other, which could lead to an inappropriate business decision.

Implementing a recognized quality system such as an ISO 14000 or equivalent program provides the tools to understand, document and quantify quality-related issues. Quality management with a quality system shows a payback rather than a "cost of doing business." Efficiency projects are also more likely to be supported by management that has already acknowledged the intrinsic value of a quality system.

Quality systems also offset some of the costs associated with project identification and quantification. Installing a quality system assists in identifying gaps or inaccuracies in existing procedures and processes. One example might be direct energy savings achieved through a documented and repeatable sensor-calibration procedure. Prior to the implementation of a quality system, it would not be unusual for two people to calibrate the same sensor in two different ways, resulting in the process operating at two slightly different levels or efficiencies.

There are a number of ways to measure product quality based on the residual stone remaining in the product after calcining, which can be identified or quantified by either a loss on ignition test (LOI test) or a CO_2 analysis. In simple terms, the LOI test uses a measured sample of finished lime which is weighed, heated and weighed again. The difference in weight before and after heating is an indicator of the amount of stone still in the product. The maximum allowable difference depends on the end-user's specification, but it is typically approximately 3%.

It has been proven in practice that partially calcined limestone that is allowed to cool cannot be reprocessed to recover the remaining lime, resulting in failure to achieve quality standards and disposal of the off-specification product.

For illustration purposes only, assume that 1% of total throughput is discarded because it fails to meet the accepted LOI range. Also assume that the LOI of the waste is approximately 15% and that kiln efficiency is 6.6 GJ/tonne.[1] A kiln that produces 102,000[1] gross tonnes would then waste approximately 5700 GJ of burner energy annually. At an average burnertip gas cost of $3.03/GJ[1], the kiln energy cost would be approximately $17,000 annually.

As the LOI of the product moves closer to the accepted specification, there is a slight increase in energy lost as the stone has consumed more energy to be dissociated to the higher lime content.

Added to this cost would be energy consumed during the preparation of the limestone and the lost revenue costs because this product can no longer be sold.

OPERATIONAL MEASURES AND PROCEDURES

- Operate at maximum production levels and minimize transient operations wherever possible, thereby eliminating start-up and shutdown product losses.
- Limit over-handling and “bypass” operations whenever possible through process changes or the use of variable speed drives.
- Identify and quantify product quality issues or scrap costs.
- Implement a management system to routinely monitor and quantify product losses over a period of time, and provide a system for reporting.
- Implement calibration procedures and policies for critical sensors and operations.
- Investigate means for recovering encapsulated limestone or developing a market for its use, i.e., can the cement industry re-crush and utilize mixed lime and stone in a specific application?

CAPITAL PROJECTS

- Replace inferred weight measurement with direct measurement.
- Implement a full quality management system (i.e., ISO 9000 or 14000 or equivalent).

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Process measures or procedures (each element)	Resource or capital	Six months to three years	—
Quantify scrap costs	Resource	Six months to three years	—
Scale replacement	Capital	Six months to three years	—
Implement quality system	Capital	More than three years	Adds marketing value

[1] Mineral and Metals Working Group of the Industry Issues Table: *Minerals and Metals Foundation Paper*, March 1999 (available at http://www.nccp.ca/html/index.htm, “Issue Tables” and “Industry”).

6.2 MATERIAL-HANDLING SYSTEMS

Most product within a lime facility is handled through the use of belt conveyors and elevators. Most facilities utilize a dozen or more small-horsepower, independently activated units. This makes an overall control strategy difficult. However, there are means for reducing energy consumption over and above those mentioned in Section 5.6, "Electric Motors."

Covering the limestone-handling systems helps to protect the raw product and minimize moisture gains during processing, and can assist in reducing belt slippage due to icing in cold climates. Proper covering may also reduce the number of start-up issues, allowing the handling system to be shut down when not in use.

OPERATIONAL MEASURES

- Maintain rollers, gears, sprockets, etc. to minimize friction caused by stiff or seized bearings.
- Use synthetic lubricants as applicable.
- Shut down systems when not in use and avoid interlocking with systems that must be run independently.

CAPITAL PROJECTS

- Purchase high-efficiency motors.
- Minimize product handling.
- Match process speeds through the use of variable speed drives.
- Investigate the use of covers on limestone-handling systems.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Maintenance issues (each element)	Resource	Six months or less	—
Capital projects (each element)	Capital	Six months to three years	Except covered conveyors
Covered conveyors	Capital	More than three years	Depends on climate

6.3 LIMESTONE STORAGE

In most aspects of limestone processing, it is important to keep water content to a minimum. The stone absorbs water after the blasting process, in the base of the quarry, on conveyors and during transportation. There are two primary difficulties for the calcining process when the feedstock is wet. One is that prior to heating the stone to the calcining point, the moisture must first be driven off or evaporated, a potential source of energy loss. Approximately 1,500 MJ (1400 Btu) is required to elevate the temperature of a pound of water to the evaporation point (latent heat plus assumed sensible heat). This value will vary depending on the drying effect that the airflow has on the stone and the initial temperature of the moisture. It should, however, be noted that there will always be some waste heat in the exhaust stream, and it is this low-quality energy that is utilized for drying the raw stone. More investigation may be required to quantify the total effect of dry versus wet feedstock on kiln energy efficiency.

A second problem is that the limestone may freeze in clumps during the winter months, making handling and bin storage evacuation difficult. Some sites use intermittent propane heaters or lances to melt the ice that holds the stone together. Direct-fired or direct-contact steam equipment tends to add high amounts of moisture to the storage and therefore compounds the problem once the heat source is removed.

If some form of wasted heat energy is available in the vicinity, then it may be more cost-effective to use this energy, rather than a primary, purchased fuel, at that location. For example, excess air from the cooler could be used to avoid freezing in a local stone storage bin. Caution must be exercised to ensure that the waste heat recovered will not adversely affect the limestone, either through adding moisture or introducing flue gas contaminants.

OPERATIONAL MEASURES

- Avoid storage areas with ground-water difficulties.
- The quarry floor/blast lay-down zone should be maintained as appropriately as possible to avoid any standing water.
- Transport or cover limestone as quickly as feasible.

CAPITAL PROJECTS

- Cover limestone storage piles.
- Preheat stored stone with kiln exhaust or excess cooler air, as applicable.

If water and freezing are still a problem, an indirect heating arrangement would be preferable to a direct system for intermittent heating. One option to investigate is routing a portion of the kiln exhaust stream or excess cooler air to the storage hopper for continuous, free heat for thawing. The moisture content and temperature of the exhaust (to prevent condensation), as well as its gas chemistry (to maintain the limestone's quality) should be considered. The physical location of the stone storage bins in relation to the kiln exhaust may also make this a difficult proposition.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Operational measures (each element)	Resource	Six months or less
Capital projects (each element)	Capital	More than three years

6.4 CRUSHERS AND VIBRATING FEEDERS

The type and style of crushers used on site influence the consistency of stone size and overall efficiency of the process. Depending on the characteristics of the limestone being processed, certain crushers will produce more uniform stone sizes. This in turn avoids unnecessary or uncontrolled crushing, channelling more energy being used in the production of the higher value product and less energy in producing fines or stone dust. Proper primary crushing may lessen the amount of secondary crushing, supporting the goal of minimizing product handling.

Replacing a crusher is a major capital investment, and it may be economically more feasible when an existing unit has become capacity limited or has reached the end of its useful life. Crusher selection will be directly influenced by the make-up of the limestone being processed and the desired shape and size of the lime product.

Vibrating feeders can be discussed in similar terms as motors, and most of the tips apply to both.

OPERATIONAL MEASURES

- Avoid excessive motor idling.
- Replace conventional motors with high-efficiency motors.
- Ensure that vibrating feeders are properly mounted.
- Do not interlock vibrating feeders with conveyors if the two are required to operate independently.
- Maintain crushers to ensure proper operation and that limited re-crushing is required.

CAPITAL PROJECTS

- Replace conventional motors with high-efficiency motors.
- Operate crushers only as required to target “once-through” crushing.
- Eliminate operations that require rehandling.
- Replace existing crushers with higher-efficiency crushers.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Operational measures	Resource, training	Six months or less
High-efficiency motors	Capital	Six months or less
Operate crushers only as required	Resource	Six months to three years
Eliminate re-handling	Capital	More than three years
Higher-efficiency crushers	Capital	More than three years

6.5 SCREENING

Better screening can ensure that limestone has a tight size range and will enable uniform calcination, resulting in less wastage due to improperly calcined product. Non-uniform charge size may cause pockets of compaction in a preheater or vertical kiln, which forces flue gases into certain defined channels, creating temperature gradients across the product charge.

This is primarily a product quality issue, but relates to energy efficiency by avoiding losses associated with wasted or unsaleable product. Quality cost issues are addressed in Section 6.1, "Process Flow, Handling and Product Quality."

Prior to any changes in screening equipment or procedures, it is necessary to investigate and quantify improvements gained through screening and product sizing changes.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Screening modifications or replacement	Capital	More than three years

6.6 LIMESTONE PREHEATERS

The design and cost of a preheater is very specific to the kiln with which it will be used. In most applications, adding a preheater to a long rotary kiln will not effectively recover its cost, unless increased productivity and throughput is also required.

A preheater may not be desirable or provide any reasonable economics in batch or swing kilns due to short product runs and rapid changes in product type.

New, high-efficiency preheaters offer more even heating of the stone as they avoid or minimize cold corners found in earlier conventional square units. Feed mechanisms have also been optimized and are more efficient than the older stoker-style units.

On shaft kilns, continuous feed systems can increase system efficiency by reducing cool-down and warm-up periods common with straight batch systems.

OPERATIONAL MEASURES

- Optimize the feed rate.
- Minimize ambient air infiltration into kilns (avoid in-leakage).

CAPITAL PROJECTS

- Install continuous feed systems as applicable.
- Upgrade to modern-style preheaters.
- Add a new preheater and combine energy savings with increased throughput to eliminate or lessen the use of less efficient kilns.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Operational measures (each element)	Resource	Six months or less	—
Upgrade preheater	Capital	More than three years	—
Add new preheater	Capital	More than three years	Increased product capability

6.7 LONG ROTARY KILNS

In long rotary kilns, the exhaust temperature is typically too high to be handled directly by either a baghouse or a precipitator unit. As discussed in the previous section, if there is limited requirement for increased product throughput, then it may not be economical to install a preheater. The exhaust air must then be tempered to lower the temperature to a level that the baghouse or precipitator can handle. Three ways to achieve this are to add dilution or tempering air, use induction cooling towers or use water spray systems downstream of the kiln.

Tempering the exhaust air with ambient air has the drawback of increasing the fan requirements (sometimes through adding more fans) and the associated energy consumed. It may also increase the flow rate of air beyond the capability of the baghouse or precipitator, and additional capital investments may be required to rectify this.

An induction tower helps to cool the exhaust stream by increasing the surface area, allowing the tower to act as an air-to-air heat exchanger. The increased piping will add load on the draft fans.

Water injection into the kiln exhaust is used in certain situations to reduce the temperature of the flue gas through evaporative cooling. When this occurs, the cooler exhaust stream does not require as much dilution air, which in turn reduces the dilution fan loads. Also, the draft fans become more effective as they are now moving cooler, denser air.

Depending on the type of fuel being consumed, water injection used in conjunction with precipitators can also improve the efficiency of the precipitators by allowing for more effective ionization of the exhaust stream, further lowering energy consumption.

The amount of water injected into the flue gas stream is tightly controlled so that the temperature does not fall below the dew point and result in the formation of slurry.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Minimize dilution air	Capital	Site-specific	—
Evaporative cooling	Capital	Site-specific	Requires additional research

6.8 COOLERS

The Niems-style cooler is currently regarded as the most efficient type of cooler. It is able to cool the product with airflow approximately equivalent to the secondary combustion air requirements of the kiln. This reduces the amount of fan power wasted by adding more air or by exhausting of excess. It also ensures that all of the heat recovered in the air is reused.

A grate-style cooler, on the other hand, requires much larger quantities of air, resulting in more air than the kiln can handle, that air being of lesser quality (lower heat content). Typically, a portion of this air must be exhausted, resulting in energy being lost in the form of excess fan load and lost heating content of the exhausted air.

If there are nearby uses for some of this excess, lower grade heat, such as a mill operation or stone storage pile thawing, then some energy can be recovered.

It is generally not cost-effective to replace coolers for energy efficiency gains alone.

OPERATIONAL MEASURES

- Investigate opportunities for excess cooler air usage.
- Utilize excess cooler air for primary air supply.
- Optimize cooler airflow to balance preheated air and product temperature requirements.

CAPITAL PROJECTS

- Upgrade fans to high-efficiency units.
- Upgrade cooler to Niems-style (or equivalent) at the time of replacement.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Operational measures (each element)	Resource	Six months or less
Install upgraded cooler	Resource	Six months to three years

KILN-RELATED TIPS 7.0

7.1 KILN REFRACTORY

Equipment manufacturers in Europe have been developing and using refractory with higher insulation values for several years. As energy costs are substantially higher in Europe, this alternative refractory is a viable option. Although such modified refractory is not cost-effective and therefore not widely accepted in Canada, it still warrants mention.

Single-layer, high R-value refractory material can be used in both rotary and vertical kilns. When using this type of insulation, there is usually a trade-off with the life expectancy due to an increased wear rate.

Multi-layer firebrick (high R-value brick used to back a high-duty contact brick) has displayed some reliability issues and also shorter life spans because of the thinness of the contact brick and difficulties with layer separation. One estimate indicated that the life of this type of kiln lining could be reduced by 50%, which substantially increases overall downtime, re-insulation and resource costs.

Increasing the overall thickness of the brick – to either extend the life expectancy or increase the R-value – reduces the kiln's volume, which reduces the quantity of product that can be processed. This may still be an acceptable method for reducing energy consumption in an intermittent or lower utilization kiln that would be unaffected by reducing the processing rate. However, the lower use may not show the economic gains of increasing the efficiency.

Relining the kiln with better insulation changes the heat balance of the kiln and requires a review of the overall process, including changes to the fuelling rates and control strategies. Energy savings are immediate, and operators will need to "back off the throttle" to maintain proper temperatures.

Providing that the residence time is still acceptable and that product quality does not suffer, the other alternative is to maintain the same firing rate but increase the production rate on the kiln.

Preparing a kiln heat-loss study will establish the most cost-effective material for selection, the time for refractory replacement and the costs associated with the above. The study will determine if increased heat loss from the kiln would ever justify early refractory replacement.

A newer style of refractory material, with a textured or ribbed backing, increases the R-factor by adding a dead air space. It is claimed to increase the R-factor over standard refractory and provide a similar life expectancy.[1]

[1] Source: RHI Canada Inc. (Formerly VRO Canada Inc.)

Along these same lines is the use of thermographic or infrared scanners to analyse the heat loss from the kiln. Some infrared equipment may be under-utilized if it is currently being used solely to identify insulation damage or "hot spots" to prevent kiln damage. Some data manipulation from these systems may allow for measurement or trending of heat loss as compared to an ideal condition.

OPERATIONAL MEASURES

- Seal kiln systems to minimize ambient air infiltration or radiant heat loss.
- Optimize refractory replacement periods.
- Prepare a kiln heat-loss analysis.
- Replace conventional brick with higher efficiency alternatives, maximize refractory R-values and optimize kiln controls.

CAPITAL PROJECTS

- Double-brick the kiln.
- Use thermographic or infrared monitoring for heat loss trending.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Seal kiln systems	Maintenance	Six months or less	—
Optimize refractory replacement periods	Maintenance, resource	Six months or less	—
Prepare kiln heat-loss analysis	Capital	Six months to three years	—
Maximize insulation R-value	Resource	Six months to three years	—
Double-brick kiln	Maintenance	No payback	Possible productivity impact
Thermographic or infrared heat-loss trending	Capital	Unknown	Requires additional research

7.2 COMBUSTION CONTROLS

Combustion air and fuel controls are two of the most critical and complex variables in efficient kiln operation. Oxygen content greatly affects product quality and energy consumption; controlling it, therefore, has great economic advantages.

As an illustration based on comparative analysis, in a natural-gas-fired kiln, each 1% oxygen content at the sensor represents an additional 4.8% excess airflow. Using the previous example of a kiln producing 102,000 tonnes of product annually at a rate of 6.6 GJ/tonne and a cost of gas at approximately $3.03/GJ, reducing the excess air content would save approximately $22,000 annually. The excess 5% airflow increases the fan load by an equivalent amount.

Combustion controls are highly site-specific, and the type of control depends on the overall system design, making economics and associated payback values site-specific. The illustration of the cost of excess air can be used as a basic guide for the advantages of improving fuel and air control. Where combustion control simple payback periods are available or applicable, they have been included in the analysis tables.

CAPITAL PROJECT

- Implement and operate on-line automated burner and air controls as much as possible, as they are able to identify irregularities and adjust rapidly.

7.2.1 Combustion Gas Analysis

The internal kiln environment tends to cause plugging and reduces uptime capability in some combustion gas sensors, but measurement still remains an important part of supplying data for kiln control. Intermittent or timed sampling can provide accurate flue gas readings at preset measuring intervals. This extends the sensor's life by utilizing a purge sequence between measurements, effectively protecting the sampling tips from fouling or plugging. Frequent, automated calibration procedures must be performed.

Many industrial applications utilize zirconium oxide sensors to measure O_2 content in exhaust streams. The older the technology used in the cell, the less confidence the absolute measurement of the O_2 content in the lower oxygen ranges will be.[1] Also, many of these older cells have a calibrated range of 2% to 20% O_2 content. If a kiln is desired to operate at a 3% O_2 content, then the sensor will be operating in the lower 5% of capability. Excellent electronics and linearizers are required to amplify the reading accurately.

Furthermore, the sensor voltage output is affected by the temperature of the exhaust stream (a temperature change of 100°F, or 55°C, represents approximately 4% voltage output differential) so it is important to calibrate both the O_2 sensor and the temperature-measurement device. Accuracy can be improved if a second exhaust gas is measured and the results are cross-referenced to determine the intersecting point on the stoichiometric curve.

New zirconium oxide sensors have better calibration procedures and improved electronics that provide more consistent and accurate measurement.

A paramagnetic oxygen sensor – one that provides a more linear measurement and excellent accuracy on low oxygen mixtures (less than 10%) – is another option. It is slightly more expensive than a conventional zirconium-style unit but may offer improved accuracy, as well as a longer life expectancy.[1] Recent improvements in sampling methods have made the sensors even more robust and reliable.

[1] Source: CEM Specialties. See the Web site at http://www.cemsi.on.ca/abouthtm.htm.

The capabilities of sensors, metering and monitoring are advancing very quickly, and new and improved systems should be investigated continually. With the overall impact of oxygen content on operating costs and product quality, it is crucial to ensure that measurements are accurate, repeatable and reliable.

OPERATIONAL MEASURES

- Ensure routinely that all sensors are properly calibrated.
- Investigate sampling procedures in order to ensure minimal sample tip plugging.

CAPITAL MEASURES

- Investigate updating older O_2 sampling equipment with new zirconium-oxide sensors or paramagnetic sensors.
- Replace relative airflow sensors with absolute measurement in the form of Pitot tubes or a hot-wire mass airflow meter.

7.2.2 Airflow Measurement

Improved airflow measurement and control also results in more uniform product and higher process efficiency. Inferring flows and controlling creates inherent inaccuracies as fans wear, speeds vary and ducts clog. Direct measurement in the form of Pitot tubes ($3,000–$5,000) or hot-wire mass airflow sensors ($7,000–$10,000) supplies superior measurement of airflows compared with fan motor amp measurements, which change over time.

7.2.3 Fuel Control

Estimating the economics for fuel, air and mixture control is difficult because of the widely varied procedures and equipment currently employed. The key is to clearly understand how an existing system is operating and which parameters would provide the best benefit through more accurate control. The value of replacing existing measurements and controls is lessened if the inferred measurements are regularly checked and verified to be accurate.

Having stated this, it is important to reiterate the savings potential for kilns that operate with less than accurate measurement and control systems. As with the example shown in Section 7.2, each 1% oxygen content at the sensor, over and above what is needed, represents additional fuel costs of approximately $22,000 per year.

7.2.4 Burners

Many burner manufacturers supply new-technology burners to kiln users. They are designed to perform specific functions as the kiln design dictates. The amount of turbulence, swirl, primary and secondary air, and the flame length and shape (to name a few of the parameters) are all site- and kiln-specific.

The most common strategy is to reduce the primary air stream to the lowest amount possible while still achieving the required injection velocity of the fuel, resulting in a longer, better distributed flame contacting or radiating to more of the kiln charge.

Reducing primary air requirements and preheating secondary air from the cooler to 700–1100°C (1300–2000°F) increases overall efficiency. Pillard suggests that reducing primary air by 4% and replacing it with secondary air at the temperatures given above can result in overall fuel savings of approximately 1.5%. See the Web site at http://www.pillard.com.

Some investigation has been performed to quantify the value of utilizing indirect fired burners in solid-fuelled kilns, but the results to date have been inconclusive.

- Reduce supply line and control valve restrictions to decrease the primary fan loads.
- Investigate new burner technologies.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Accurate equipment calibration	Resource/training	Six months or less
Automated on-line controls	Capital	Six months to three years
Direct airflow measurement	Capital	Six months to three years

7.3 FUEL HANDLING

As discussed in Section 2.2, “Energy Use and Breakdown,” the preparation and use of some fuels entails additional costs and related energy consumption.

7.3.1 Fuel Oil

Depending on the climate and the grade of fuel oil being consumed, the oil may have to be heated to allow easier pumping and better atomization at the burner. Higher-viscosity fuel oils will require more heating, especially during cold weather.

OPERATIONAL MEASURES

- Maintain pumps and supply systems to avoid leakage.
- Limit bypass pumping to the minimum acceptable for normal kiln fuelling rates.
- Preheat the storage tank and oil to the minimum temperature for acceptable pumping.

CAPITAL PROJECTS

- If additional oil heating is required for combustion purposes, heat only the oil to be used and not the bypass as well.
- Use high-efficiency heating methods for oil.
- Insulate above-ground storage tanks to reduce heat loss.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Operational measures (each element)	Resource	Six months or less
Capital projects (each element)	Capital	Six months to three years

7.3.2 Coal and Coal Derivatives

Coal and coke accounts for approximately 40% of the total fuel consumed by the lime industry. This is due to its relatively low cost and its high radiant heat capability, thus providing excellent heat transfer to the charge.

One drawback of coal and coke is that it requires grinding or milling to be transformed into a usable, efficient form. Solid-fuel preparation devices consume energy and require auxiliary fans to transport the resulting finely ground fuel in a fluidized form. Heated air streams are supplied to the mill to help dry the fuel during grinding. A 1992 U.S. study shows that the energy-consuming pulverizing ancillaries represent an incremental cost of approximately 20% above that of coke and an additional 13% over coal purchase prices.[1]

Replacement of a static classifier with a dynamic one brings efficiency gains through avoiding over-grinding of the fuel to ensure accurate particle sizing. This can reduce the quantity of unburned fuel in the fly ash or slag at the exhaust end of the kiln. Energy requirements to operate the classifier are negated by the mill energy savings, giving an overall increase in efficiency equal to the gain in the kiln.

Using properly sized fuel can increase efficiency by 5–10%. Unburned fuel passes through the kiln and can bond with other substances in the flue gas adding to the formation of slag. This slag could be crushed and ground for use again to recapture the fuel energy, but the preparation process adds to energy consumption.

[1] Enbridge Consumers Gas. See the Web site at http://www.cg.enbridge.com.

OPERATIONAL MEASURES

- Ensure proper grinding to meet the optimum fuel particle size without excess grinding.
- Reduce fuel pumping and movement as much as possible.
- Size mill according to loads.

CAPITAL PROJECTS

- Investigate using temperature- and flow-matched heated air streams (use mid-section of cooler to supply low-quality heat and minimize diluting high-quality heat from kiln; not applicable if process is cooler air limited).
- Replace older or ineffective mills with properly sized grinding/preparation mills (economics may not be favourable because of high capital cost).
- Ensure that coal and coke are stored in a fashion that minimizes moisture gains; investigate enclosed storage options.

7.3.3 Alternative Fuels

The impact and value of utilizing alternative fuels (such as tires and waste oil) has not yet been determined. The use of some of these alternative fuels has been demonstrated in cement kilns, but the information is not directly transferable because of differences in operational temperature and product chemistry.

7.4 LEAKAGE

One area of kiln inefficiency is the energy lost through ports, openings, cracks and hatches. The energy loss through openings can occur in three fashions.

Convective losses occur when hot gases are pushed out of the kiln into the surrounding environment. This represents air that has been heated but does not do any useful work. Actual losses will be based on the temperature of air escaping and the volume, which in turn depends on the pressure differential and the size of the opening.

Radiant losses occur when infrared heat (light) is lost through openings. The loss is partially dependent on the emitter – in this case the flame, firebrick and glowing lime – and partially on the absorptivity of the surrounding surfaces. A table supplied in the CIPEC Energy Efficiency Guide suggests that a small, hatch-sized opening of 230 cm^2 (36 sq. in.) can emit approximately 125 GJ (120 mmBtu) of radiant energy per year.

When air is introduced into a low pressure area of the kiln (commonly termed **in-leakage**) through seal leaks, doors or covers, efficiency is reduced. This air intake is also uncontrolled and susceptible to variations, making overall kiln air and fuel control more difficult.

In-leakage also adds to the load induced on the fans. This is especially undesirable in cases where an induced draft fan has been sized to the point that it becomes the limiting factor in kiln operation. Air leaks closer to the feed end of the kiln can also affect the measurement of remaining oxygen in the air stream without significantly adding to the combustion process.

7.5 KILN INTERNALS

Internals such as dams, trefoils, mixers and lifters can assist with two issues in a rotary kiln: increased product mixing and reduced laminar gas flow.

Rotary kilns have a characteristic product flow pattern that results in larger charge pieces sitting on top of smaller ones and forming a kidney-shaped cross-sectional pattern in the bed. This form prevents heat from being distributed evenly to all the stones as they tumble. This is less of an issue in preheated kilns because the smaller charge pieces become calcined in the preheater, and then are protected from hard burning by the large charge pieces surrounding it within the kidney in the kiln.

In long rotary (non-preheated) kilns, adding specific internals (such as lifters, metallic crosses or trefoils) can increase the charge mixing, resulting in more even product burning. This also increases tolerance of the feed size ratio of the charge while maintaining an even quality of burn across the charge.

A drawback of increasing the charge turbulence is that it will increase agitation and therefore increase the quantity of breakage and fines.

Installing internals to decrease the laminar flow of the flue gas does not affect the charge condition but will increase the air turbulence, resulting in an increase in heat transfer to the product and more thorough air-fuel mixing.

OPERATIONAL PROCEDURE

- Investigate current heat transfer within kilns and the benefit of adding charge or combustion gas baffles.

7.6 VERTICAL KILNS

The efficiency of vertical kilns is influenced in many of the same ways as rotary kilns. Vertical kilns work on a batch-type system rather than continuous feed, and the upper kiln area is used for preheating. Typically, the kiln would be shut down, the batch would be charged and the burners would be re-fired. The calcined limestone is then removed from the bottom of the kiln through a cooler system at a controlled rate. Once the feedstock lowers to a preset level, the process repeats.

The addition of a closed charge feed system eliminates the need to shut the kiln down for charging, thereby reducing transient operations. The kiln is not affected by adding the charge as it is introduced via an airlock arrangement, which has minimal affect on the combustion process.

Recent developments include the addition of perimeter burners (where the existing kiln was not designed with them). These burners utilize high-exhaust gas recirculation flow rates to extend the flame far into the product and supply more even heating without hard-burning lime that is close to the burner. In one application, perimeter burners have increased product throughput capability by 35% while decreasing fuel consumption.

OPERATIONAL PROCEDURE

- Maintain close screening practices.

CAPITAL PROJECT

- Prepare a fuel consumption study over time to establish refractory wear impacts.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Screening practices	Resource	Six months to three years
Fuel consumption study	Capital	Six months to three years

7.7 CYCLONES

Cyclones and multiclones, if utilized, are typically placed in the exhaust stream between the kiln and the induced draft fan and can collect some particulate matter through the use of centrifugal forces. They use no energy (other than the increased restriction imparted to the induced draft fan), offer low maintenance and do not require any flue gas tempering. Typically, they can remove approximately 70% of the particles in the exhaust stream.

OPERATIONAL PROCEDURE

- Use cyclones and multiclones to remove as much particulate matter as possible before admitting flue gas to baghouses or precipitators.

7.8 BAGHOUSES AND PRECIPITATORS

Baghouses and precipitators have an impact on energy efficiency, but it is much more critical to ensure that they operate properly and are designed to deal with the temperature and particulate level in the exhaust.

- Utilize “on-demand” cleaning procedures as required, not on timed schedules.
- Minimize flue gas dilution through the use of higher-temperature baghouse bags.
- Investigate using evaporative cooling with precipitators.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK	COMMENTS
Optimized cleaning cycle	Resource	Six months to three years	—
Minimized dilution air	Capital	Six months to three years	—
Evaporative cooling study	Capital	Unknown	Requires additional research

7.9 BRIQUETTING PROCESSES

Briquetting is the process of compressing lime dust into small (approximately 1 in. × 2 in. × 1/2 in.) hard-shelled briquettes. This lowers the dust associated with handling of lime during transportation and process end-use. These briquettes can also be coated – with iron oxide, for example – for specific end-use applications. Briquetting is not a common practice across all facilities, but it may be economically advantageous if a specific facility has an excess of lime dust and a market for the briquettes.

OPERATIONAL PROCEDURES

- Eliminate or reduce dust feed bypass systems.
- Ensure that equipment is operating at its maximum efficiency and briquette breakage is kept at a minimum.
- Avoid excess handling of completed briquettes.
- For intermittent operation, operate equipment during off-peak hours only.

CAPITAL PROJECTS

- If necessary, use mould coatings to facilitate briquette release from moulds.
- Retrofit with higher-efficiency briquetters that utilize high-efficiency motors.

MEASURE	TYPE OF INVESTMENT	SIMPLE PAYBACK
Operational procedures (each element)	Resource	Six months or less
Mould-release agents	Capital	Six months to three years
Replacement with high-efficiency machines	Capital	More than three years

INDUSTRY CONTACTS

NATURAL GAS UTILITIES

B.C. Gas Utility Inc.
Gary Hamer
Energy Efficiency Manager
Market Development, B.C. Gas
2nd Floor, 4190 Lougheed Highway
Burnaby BC V5C 6A8
Tel.: (604) 293-8473
Fax: (604) 293-8850
E-mail: ghamer@bcgas.com

SaskEnergy
Bernard Ryma
1945 Hamilton Street
Regina SK S4P 2C7
Tel: (306) 777-9368
Fax: (306) 525-3422
E-mail: bryma@SaskEnergy.sk.ca

Enbridge Consumers Gas Company Limited
Masoud Almassi
Manager of Industrial Marketing
2235 Sheppard Avenue East
Atria II, 10th Floor
North York ON M2J 5B5
Tel.: (416) 496-7110
Fax: (416) 496-7182
E-mail: masoud.almassi@cgc.enbridge.com

ATCO Gas
Mark Antonuk, Supervisor
Commercial Industrial
Marketing
909-11 Avenue South West
Calgary AB T2R 1L8
Tel.: (403) 245-7199
Fax: (403) 245-7405
E-mail: mark.antonuk@atco.gas.com

Centra Gas Manitoba Inc.
Dieter Bartel
Commercial Business Representative
444 St. Mary Avenue
Suite 510
Winnipeg MB R3C 3T7
Tel.: (204) 925-0240
Fax: (204) 925-0810
E-mail: dbartel@wei.org

PROVINCIAL GOVERNMENT ENERGY MANAGEMENT PROGRAMS

British Columbia
Energy Management Branch
Energy Resources Division
Ministry of Energy, Mines
and Petroleum Resources
617 Government Street, Room 418
Victoria BC V8V 1X4
Tel.: (250) 952-0583

Saskatchewan
Howard Loseth
Energy Conservation Engineer
Energy Development Branch
Saskatchewan Energy and Mines
2101 Scarth Street
Regina SK S4P 3V7
Tel.: (306) 787-3379
Fax: (306) 787-2333
E-mail: howard.loseth@sem.gov.sk.ca

Ontario
Ontario Ministry of Energy
Myra Gerow
Commodities Coordinator
933 Ramsey Lake Rd.
Sudbury ON P3E 6B5
Tel.: (705) 670-5828
Fax: (705) 670-5803
E-mail: myra.gerow@ndm.gov.on.ca

New Brunswick
Sam McEwan
Manager of Mines and Energy
Development
Natural Resources and Energy
P.O. Box 6000
Fredericton NB E3B 5H1
Tel.: (506) 453-6637
Fax: (506) 453-3671
E-mail: smcewan@gov.nb.ca

Alberta
Energy Efficiency Branch
Alberta Department of Energy
Diana Prudy
Mineral Access and Geology Mapping
4th Floor
9945-108 Street
Edmonton AB T5K 2G6
Tel: (780) 422-9499
Fax: (780) 422-1123
E-mail: diana.prudy@gov.ab.ca

Manitoba
Ernie Armitt
Director of Mines Branch
Energy and Mines
1395 Ellice Avenue
Winnipeg MB R3G 3P2
Tel: (204) 945-8427
Fax: (204) 945-8427
E-mail: earmitt@em.gov.mb.ca

Quebec
Luc Morin
Direction de l'efficacité énergétique
Ministère des Ressources naturelles
Gouvernement du Québec
5700, 4th Avenue West
Charlesbourg QC J1H 6R1
Tel: (418) 627-6379, ext. 8036
Fax: (418) 643-5825
E-mail: luc.morin@gouv.qc.ca

Prince Edward Island
Ron Estabrooks
Energy and Minerals Branch
P.E.I. Economic Development
and Tourism
P.O. Box 2000
Charlottetown PE C1A 7N8
Tel: (902)368-5011
Fax: (902)368-6582
E-mail: rgesta @gov.pe.ca

Nova Scotia
Department of Natural Resources
Don Jones
Director of Mines and Energy
Development Division
4th Floor Founders Square
1701 Hollis Street
P.O. Box 698
Halifax NS B2J 2T9
Tel.: (902) 424-5618
E-mail: dsjones@gov.ns.ca

Newfoundland
Brian Maynard
Deputy Minister of Mines and Energy
P.O. Box 8700
St. John's NF A1B 4J6
Tel: (709) 729-2356
Fax: (709) 729-0059
E-mail: bmaynard@mail.gov.nf.ca

Northwest Territories
Jacqueline Cusveller
Mineral, Oils and Gas Division
RWED Government of Northwest Territories
Box 1320
Yellowknife NT X1A 2L9
Tel.: (867) 920-3346
Fax: (867) 873-0254
E-mail: jackie_cusveller@gov.nt.ca

ELECTRICAL UTILITIES

British Columbia Hydro
Energy Management Division
Marty Ahad
6911 South Point Drive (East 16)
Burnaby BC V3N 4X8
Tel: (604) 528-1537
Fax: (604) 528-1552
E-mail: marty.ahad@bchydro.bc.ca

TransAlta utilities
Rob Falconer
Products and Services Manager
P.O. Box 1900
Calgary AB T2P 2M1
Tel: (403) 267-2578
Fax: (403) 267-4740
E-mail: robfalconer@transalta.com

Alberta Power Limited
Nap Pepin
Commercial Sales Representative
10035-105th Street
Edmonton AB T5J 2V6
Tel: (780) 420-4102
Fax: (780) 420-7222
E-mail: nap.pepin@atcoelectric.com

Edmonton Power
Lloyd Bertschi
Program Manager
Envest (EPCOR)
Capital Square
9th Floor, 10065 Jasper Avenue
Edmonton AB T5J 3B1
Tel: (780) 412-3438
Fax: (780) 412-3346
E-mail: lqbertsc@epcor-group.com

SaskPower
Randy Graham
Manager of Key Accounts
2025 Victoria Avenue
Regina SK S4P 0S1
Tel: (306) 566-2832
Fax: (306) 566-3305
E-mail: rgraham@saskpower.sk.ca

Winnipeg Hydro
Brian Gaber
Energy Management Coordinator
223 James Avenue
Winnipeg MB R3B 3L1
Tel: (204) 986-2339
Fax: (204) 942-7804
E-mail: bgaber@city.winnipeg.mb.ca

Hydro-Québec
Ronald Martineau
Marketing Director, Hydro Québec
1010 Ste-Catherine Street West, 9th Floor
Montreal QC H3C 4S7
Tel: (514) 392-8000, ext. 8471
Fax: (514) 392-8806
E-mail: matineau.ronald@hydro.qc.ca

New Brunswick Power
Mike Keays
Industrial Customer Administrator
P.O. Box 2000
Fredericton NB E3B 4X1
Tel: (506) 458-4252
Fax: (506) 458-4000
E-mail: MKeays@nbpower.com

Nova Scotia Corporation
Ann Hope
Manager of Marketing,
Business to Business
P.O. Box 910
Halifax, NS B3J 2W5
Tel: (902) 428-6149
Fax: (902) 428-6066

Manitoba Hydro
Michael Dudar
Division Manager
Industrial and Commercial Solutions
820 Taylor Avenue
P.O. Box 815
Winnipeg MB R3C 2P4
Tel: (204) 474-4100
Fax: (204) 474-4641
Email: mpudar@hydro.mb.ca

Ontario Hydro
Bob McKeller
Energy Services and Environment
700 University Avenue (H19-A-20)
Toronto ON M5G 1X6
Tel: (416) 506-3448

New Brunswick Power
George Dashner
Energy Management Specialist
P.O. Box 2000
Fredericton NB E3B 4X1
Tel: (506) 458-3285
Fax: (506) 458-4000
E-mail: Gdashner@nbpower.com

Maritime Electric Co. Ltd.
Angus Orford
Manager of Marketing and
Corporate Communications
P.O. Box 1328
Charlottetown PE C1A 7N2
Tel: (902) 629-3628
Fax: (902) 629-3665
E-mail: orford@maritimeelectric.com

Newfoundland Power
Mervin Cranford
Energy Utilization Specialist
P.O. Box 8910
St. John’s NF A1B 3P6
Tel: (709) 737-5891
Fax: (709) 737-5339
E-mail: mcranfor@newfoundlandpower.com

Newfoundland and Labrador Hydro
Al Ballard
Manager Customer Relations
P.O. Box 12400
St. John's NF A1B 4K7
Tel: (709) 737-1754
Fax: (709) 737-1902
E-mail: aballard@nlh.nf.ca

Yukon Electrical Company Ltd.
Steve Savage
P.O. Box 4190
Whitehorse YT Y1A 3T4
Tel: (867) 633-7034
Fax: (867) 633-5797
E-mail: steve.savage@atco.ca

NWT Power Corporation
Mike Vaydik
General Manager
Box 2818
Yellowknife NT X1A 2R1
Tel: (867) 873-5281
Fax: (867) 920-2145
E-mail: nwtmines@ssimcro.com

Yukon Energy Corporation
John Maissan
Director Technical Services
P.O. Box 5920
Whitehorse, YT Y1A 5L6
Tel: (867) 667-8119
Fax: (867) 393-6353
E-mail: john.maissan@yec.yk.ca

REFERENCED PROGRAMS

Canada's Climate Change
Voluntary Challenge and Registry Inc.
170 Laurier Ave, Suite 600
Ottawa ON K1P 5V5
Tel.: (613) 565-5151
Fax. (613) 565-5743

ON SITE
c/o Energy Pathways Inc.
251 Laurier Avenue West, Suite 500
Ottawa ON K1P 5J6
Tel.: (613) 798-9393

CIPEC Secretariat
Industrial Energy Efficiency Initiative
Office of Energy Efficiency
Natural Resources Canada
580 Booth Street, 18th Floor
Ottawa ON K1A 0E4
Fax: (613) 947-4121

CEMET
Natural Resources Canada
580 Booth Street,18th Floor
Ottawa ON K1A 0E4
Tel.: (613) 947-6814

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CIPEC

For more information or to receive additional copies
of this publication, write to:

Canadian Industry Program for Energy Conservation
c/o Natural Resources Canada
Office of Energy Efficiency
580 Booth Street, 18th Floor
Ottawa ON K1A 0E4
Tel: (613) 995-6839
Fax: (613) 947-4121
E-mail: cipec.peeic@nrcan.gc.ca

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Office de l'efficacité énergétique

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The Office of Energy Efficiency of Natural Resources Canada is a dynamic organization with a mandate to renew, strengthen and expand Canada's commitment to energy efficiency in order to help address the challenges of climate change.