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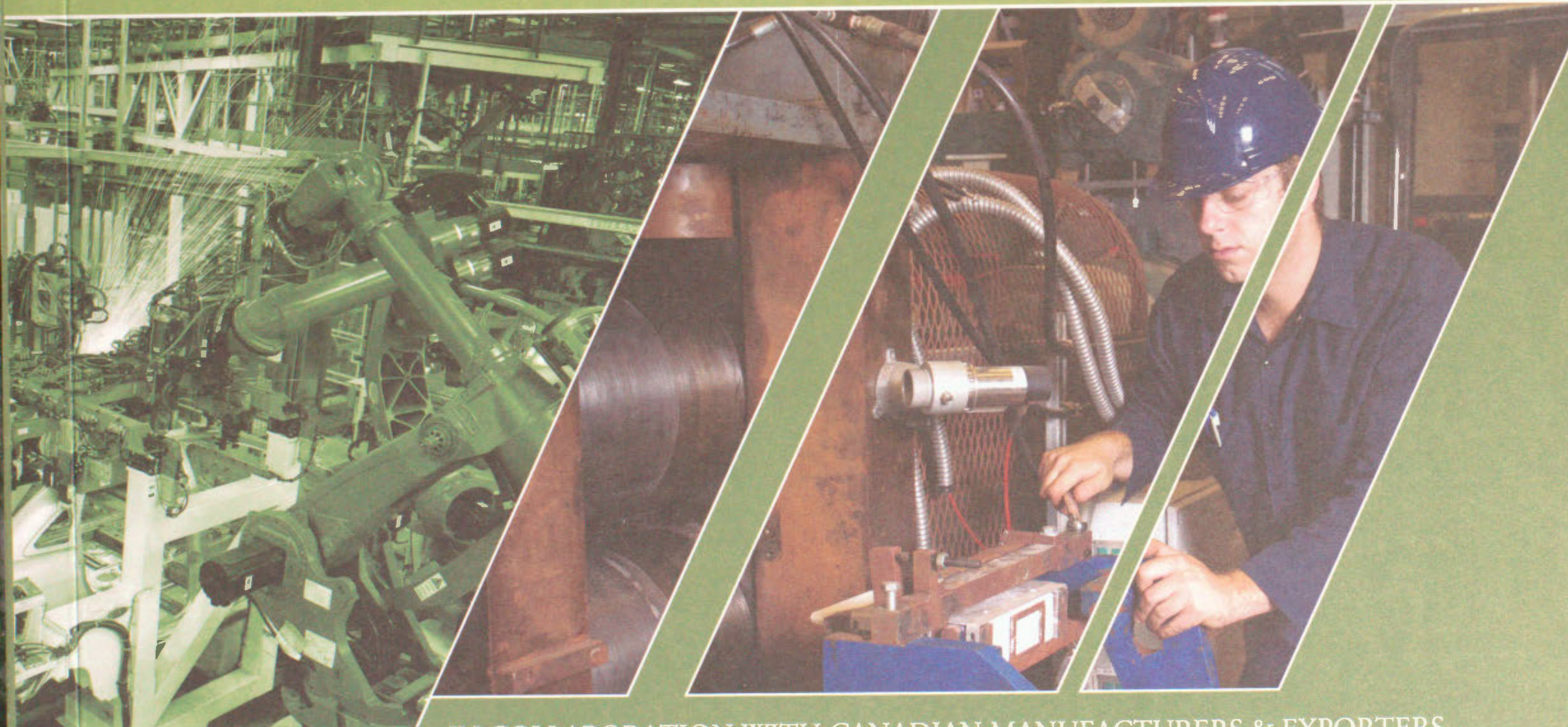
ADVANCING OPPORTUNITIES IN ENERGY MANAGEMENT IN

ONTARIO'S INDUSTRIAL AND MANUFACTURING SECTOR



IN COLLABORATION WITH CANADIAN MANUFACTURERS & EXPORTERS

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EXECUTIVE SUMMARY

Energy management (EM) can help sustain our economy and reduce industry's influence on climate change. By calculating the potential energy savings that can result from EM, this study makes the case for public policy and programs targeted to help companies in Ontario increase their competitiveness and reduce greenhouse gas (GHG) and criteria air contaminant (CAC) emissions associated with energy use.

Total Ontario industrial energy use could drop by an estimated 29 percent by 2030 if Ontario industry were to adopt economically feasible best practices, according to the EM potential analysis conducted in this study. GHG emissions would be 27 percent lower than the reference case projection, and CAC emissions would be 25 percent lower.

A total of 148 plants participated in the study between October 2008 and July 2009. EM performance benchmarking revealed how well they are managing energy use—specifically, the number of plants that have implemented technical best practices (TBPs) and management best practices (MBPs).

Technical best practices have not been widely implemented. TBPs refer to production system and efficiency measures that reduce energy use per unit of production. An example is the installation of a heat recovery system on a process exhaust stream to preheat a feed stream. Most plants have implemented less than 42 percent of possible TBPs. In particular, significant savings potential was identified in process heating—both direct (ovens, dryers, kilns and furnaces) and indirect (boilers and steam systems).

There is also great potential for Ontario industry to improve management best practices. MBPs address the people aspect in reducing energy use. In a company, an MBP is illustrated by a high level of commitment, awareness, organization and action in support of energy efficiency. An example is the adoption of a policy and plan to manage energy. Overall, 75 percent of plants in Ontario have implemented less than 48 percent of recommended MBPs.

Developing programs to increase EM best practices depends on an understanding of the challenges facing industry. The following were the top five challenges identified by participants in the study:

- Financing for energy efficiency projects is difficult to obtain;
- The payback period for energy efficiency projects is too long, or the return on investment is too low;
- It takes too much effort to access assistance, funding and incentives from existing programs;
- Companies do not have the human resources to focus on EM; and
- Production is the dominant focus, and EM is not seen as integral to production.

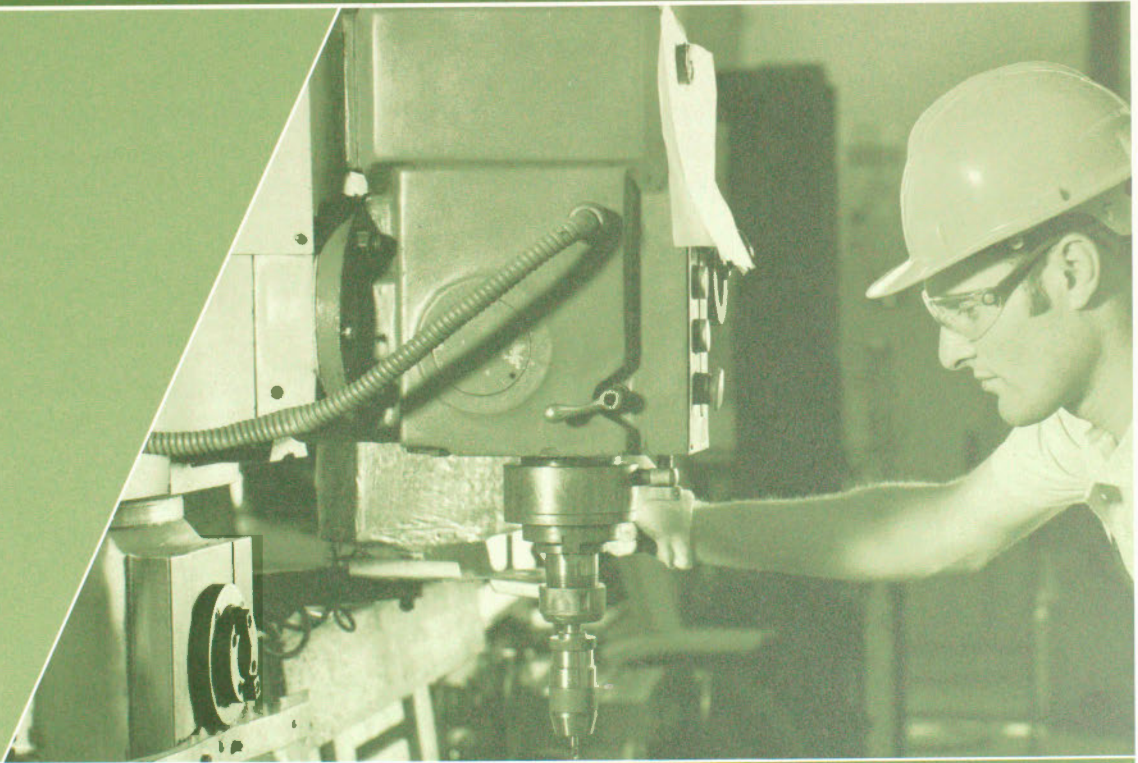
Participants also identified possible solutions to address these challenges. Together with the opportunities for enhanced EM outlined in this study's benchmarking analysis, these challenges and solutions provide the necessary input for an action plan to advance EM in Ontario industry. The following table provides examples of solutions based on the priority list of issues identified by industry.

Table 1-1: Solutions to Improve Energy Management

Category	Priority Needs Identified by Industry	Examples of Program Development/Solutions
Transaction Costs	One-stop centre or platform for programs	Create special executing agency
		Modify existing agency
Commitment to EM	Embedded energy manager	Cost-share, special-purpose, full-time-equivalent energy managers for company or plant deployment
		Cost-share roving roster of energy managers
		Design curricula and train energy managers
Knowledge of Energy Efficiency Opportunities	Centralized source of information for energy efficiency opportunities	Develop a one-source portal
Financing of Energy Efficiency Projects	Incentive to develop business case (including a detailed feasibility assessment)	Provide grants on a cost-share basis
Product and Service Availability	Energy courses and a plant assessment track for universities and colleges	Develop provincial strategy and curricula
		Request for proposals for delivery
Financing of Energy Efficiency Projects	Incentive based on amount of energy saved	Provide performance-based incentives
	Fixed-cost incentive for prescribed equipment	Provide rebates and incentives
Product and Service Availability	Funding and centres for innovation and commercialization of energy efficiency technology	Develop better co-ordination among existing agencies
		Create enhanced productivity audits that identify innovation deployment solutions for EM and clean technologies
Product and Service Availability	Certified service providers	Create certification program
Knowledge of Energy Efficiency Opportunities	Market knowledge centres	Create special executing agency
		Develop better co-ordination among existing agencies
		Develop a one-source portal

Many programs based on the above suggestions are already being offered to Ontario industry. The pressing issue is how to make them more effective in light of the barriers and opportunities identified in this study. This study's technical and management best practices analysis reveals substantial room for improvement, much of which can be addressed through training and capacity building. Enhancing EM in Ontario industry has the potential to generate significant benefits for Ontario's economic prosperity and for the environment.

1 INTRODUCTION



1 INTRODUCTION

1.1 Background and Objectives

EM is a core strategy to help sustain the productive sectors of our economy and reduce industry's influence on climate change. EM helps to

- reduce operating costs
- increase productivity
- promote the retention of value-added, manufacturing jobs
- reduce air emissions
- defer or eliminate the need for new energy infrastructure

Canadian Manufacturers & Exporters (CME), a long-time proponent of EM, contracted consultants to study ways to advance opportunities in EM in Ontario's industrial and manufacturing sector. This study fills critical knowledge gaps in EM potential in Ontario industry. It provides the basis for public policy and program initiatives targeted to help Ontario industry increase its competitiveness and reduce GHG and CAC emissions associated with energy use.

More specifically, this study determines the **current EM performance** of the industrial sector based on the implementation of MBPs and TBPs. This study also estimates the **economic potential** for EM, together with associated GHG and CAC emission reductions, and provides benchmarks for **GHG and CAC emissions** associated with energy use in Ontario's industrial sector. It also provides an **action plan** to accelerate implementation of best practices and increase industry's EM performance.

1.2 Study Scope

This study focuses on Ontario's industrial and manufacturing sectors, which include all industrial and manufacturing operations as defined by the two-digit North American Industry Classification System (NAICS) code level and included under NAICS 21, Mining and Quarrying (excluding Oil and Gas Extraction), and NAICS 31–33, Manufacturing. The **subsectors** relate to activities at the three-digit NAICS code level, as listed in Table 1-2.

Table 1-2: Industry Subsectors and Associated NAICS Codes and Descriptions

NAICS	Subsectors
331	Primary Metal Manufacturing
325	Chemical Manufacturing
322	Paper Manufacturing
327	Non-Metallic Mineral Product Manufacturing
3241	Petroleum and Coal Products Manufacturing
336, 333	Transportation Equipment and Machinery Manufacturing
311, 312	Food, Beverage and Tobacco Product Manufacturing
212	Mining (Excluding Oil & Gas)
332	Fabricated Metal Product Manufacturing
326	Plastics and Rubber Products Manufacturing
	Other Manufacturing (not included above)

The study was done at the industry subsector level to ensure a defensible, robust analysis. However, to maintain the confidentiality of the study's participating companies, the results are presented at an aggregate, industry-wide level and expanded upon according to key energy end uses.

2 METHODOLOGY

8

2 METHODOLOGY

The comprehensive methodology used in this study integrates two critical areas of EM analysis that, in the past, have been more commonly applied as distinct analysis tools: EM performance benchmarking and EM potential analysis.

The CME team has been at the forefront of EM benchmarking for industry in Canada and has applied the three-pronged approach described in the next section to similar industry studies conducted in New Brunswick, Nova Scotia and Alberta and in several industry sectors (including cement and oil and gas).

Through this integrated methodology, industry participants gain valuable insights into the management and technical factors affecting energy use performance. They also have an opportunity to improve performance through use of confidential benchmark reports and assessments of market conditions and EM potential. As well, policy and program decision-makers gain access to a robust, defensible analysis platform and to the insights and recommendations of industry participants.

2.1 Energy Management Performance Benchmarking

EM performance benchmarking determines the relationship between energy use performance indicators and the technical and management practices that influence performance. An EM performance benchmarking analysis provides an overview of how well a particular industry sector or subsector is managing energy, helps company participants in the benchmarking exercise to compare the performance of their own plant(s) with the overall industry performance indicators, and provides insight into the reasons why a plant's performance is high or low.

The results of this study's benchmarking analysis indicate how many best practices are currently implemented in Ontario industry and how many can still be implemented. These market penetration rates inform the EM potential analysis described in the next subsection.

EM generally takes the following three performance indicators into consideration:

- **Energy intensity** is a performance-based metric that relates energy use to production output. The performance metric can be expressed in equivalent kilowatt hours per tonne (kWh/t) of product produced and/or an energy efficiency index can be used.
- **Technical best practices** refer to production system and efficiency measures that reduce energy use per unit of production. An example of a TBP is the installation of a heat recovery system on a process exhaust stream to preheat a feed stream. The TBP performance indicator is the total number of applicable TBPs implemented at a plant (some practices can be partially implemented).
- Energy **management best practices** address the people aspect of reducing energy use. In an industrial organization, a management best practice is illustrated by a high level of commitment, awareness, organization and action in support of energy efficiency. An example of a MBP is the adoption of a policy and plan to manage energy. The MBP performance indicator is the total number of applicable MBPs implemented at a plant.

Best practices included in both TBPs and MBPs are referred to as **energy efficiency and energy conservation best practices.**

Because of confidentiality and data restrictions, the aggregated industry EM performance benchmarking analysis in this study includes technical and management best practices only. Energy intensity is excluded from the aggregate industry analysis because some plants consider production data confidential and did not report it. The need to maintain **participant confidentiality** is the other main reason why energy intensity is excluded. The energy intensity performance benchmark was developed only for individual plants and included in their individual, confidential plant report cards.

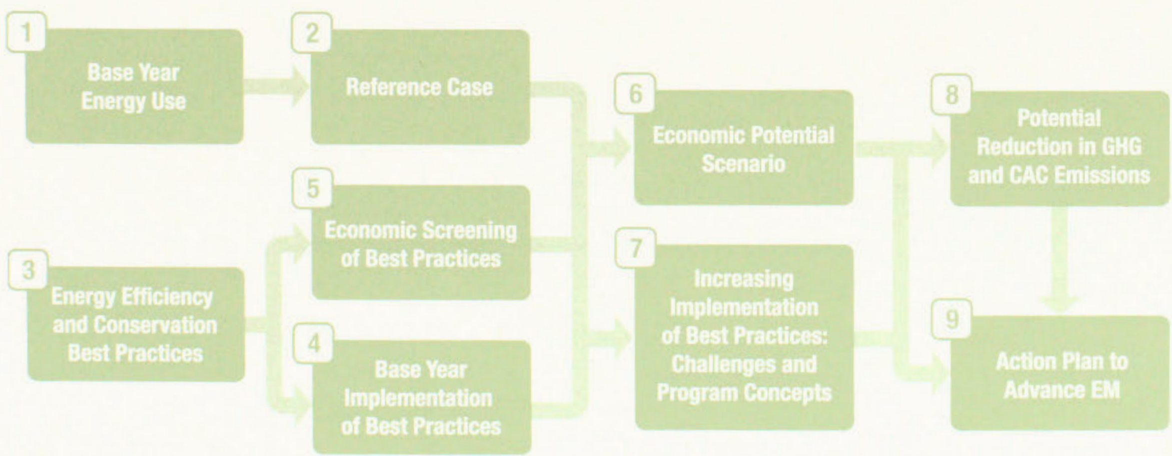
2.2 Energy Management Potential Analysis

The EM potential analysis for Ontario industry is estimated when all **economically feasible** best practices are implemented. This scenario is referred to as the "economic potential scenario." The EM potential in this scenario is estimated by comparing the reduced amount of energy use with a reference case projection of energy use in Ontario industry over a defined study period.

2.3 Integrating Energy Management Performance Benchmarking and Energy Management Potential Analysis

The integration of EM performance benchmarking and EM potential analysis is accomplished in nine steps, as illustrated in Figure 2-1 and described below. Sections 5 to 11 in this report follow the same logic flow outlined in Figure 2-1.

Figure 2-1 Integrated EM Performance Benchmarking and EM Potential Analysis



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- **Step 1 – Base Year Energy Use:** The base year is the starting point for the analysis and provides a detailed description of where and how energy is currently used in the industrial sector. In this study, the base year is 2007.
- **Step 2 – Reference Case:** This is a projection of energy use to 2030 in the absence of any new EM market interventions after 2007 (i.e., incremental to what utilities and government have already planned for this period). The reference case is the baseline against which the scenarios of energy savings are calculated.
- **Step 3 – Energy Efficiency and Energy Conservation Best Practices:** The best practices that result in energy reduction in the industrial sector are defined.
- **Step 4 – Base Year Implementation of Best Practices:** The market penetration rates of the best practices in the base year are determined through an energy benchmarking analysis. This analysis includes a survey of industrial facilities to determine the level of best practice implementation in the base year.
- **Step 5 – Economic Screening of Best Practices:** The TBPs are screened in an economic cost-benefit test to determine which practices are economically feasible from a societal point of view. The economic cost-benefit test used in this study is the total resource cost (TRC) test. The TRC test is defined in Section 9.1 and expanded upon in Appendix A.
- **Step 6 – Economic Potential Scenario:** The economic potential scenario estimates the level of savings that would occur if all the TBPs passed the economic cost-benefit test in Step 5. In this case, the TRC test is applied to the industry sectors.
- **Step 7 – Increasing Implementation of Best Practices:** The challenges and barriers that industry faces in order to implement MBPs and economically feasible TBPs are determined and prioritized based on industry workshop consultations. In turn, prioritized policy and program solutions are put forward to address the barriers and help industry implement best practices.
- **Step 8 – Potential Reduction in GHG and CAC Emissions:** The estimated energy savings in the economic potential scenario are associated with a reduction in GHG and CAC emissions. Emission factors are used to estimate the potential reduction in GHG and CAC emissions due to reduced energy use in this scenario.
- **Step 9 – Action Plan to Advance Energy Management:** Using the potential analysis results from Step 6 and the prioritized program and policy concepts defined in Step 7, an action plan is put forward that clearly defines the process and direction necessary to overcome the barriers and challenges identified in Step 7.

2.4 Project Implementation

Both the EM performance benchmarking and the EM potential analysis are informed by primary data and supplemented by secondary data to fill gaps. Data in the following main areas were collected and analysed:

- industry recruitment
- plant surveys and on-site assessments
- secondary sources
- input from stakeholders and industry

2.4.1 Industry Recruitment

The two goals of the industry recruitment process were (1) to obtain a representative sample of each subsector in terms of its energy end-use profile and implementation of best practices and (2) to obtain a representative sample in terms of small, medium- and large-size industry (size defined by energy use).

Recruitment was accomplished through targeted marketing campaigns and networking. During the recruitment stage, the uptake in the study and the representation of subsectors and size distribution were continually assessed to guide the recruitment effort. A total of 148 facilities participated in the study. An analysis of this sample is provided in Section 4.

2.4.2 Plant Surveys and On-site Assessments

The necessary primary data were obtained from participants through a combination of remote surveys and on-site plant assessments. All 148 participants completed remote surveys, and 56 also participated in on-site assessments. The main objective of the on-site assessments was to examine the accuracy of the remote surveys and identify factors to be considered when interpreting remote survey data. The following two survey instruments were used for the remote survey and the on-site assessment:

- *Energy Use and Technical Best Practice Survey:* This survey included questions about energy use and equipment and TBP implementation.
- *Management Best Practice Survey:* This survey included questions about MBP implementation.

2.4.3 Data Collection from Secondary Sources

Along with primary data and the resources to develop profiles of best practices, the study also required secondary data and input from external sources. The elements that required information from secondary sources are summarized in Table 2-1.

Table 2-1: Elements Informed by Secondary Sources

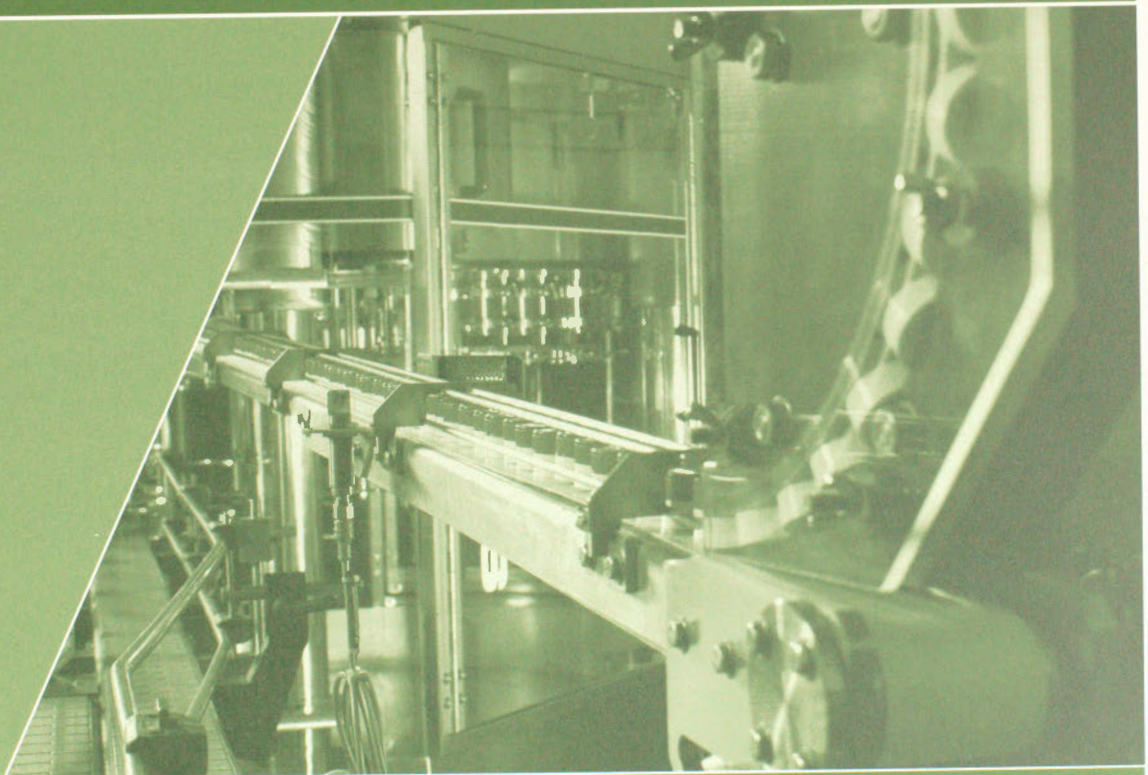
Element	Source	Applicable Section With Detailed References
Base Year 2007: Total energy use by subsector and supplementary data for energy end-use profiles	• Canadian Industrial Energy End-Use Data and Analysis Centre • Enbridge Gas Distribution • Ontario Power Authority • Statistics Canada • Union Gas • US Department of Energy – Energy Efficiency and Renewable Energy	Section 5
Reference Case: Projected Energy Use by Subsector from 2010 to 2030	• Enbridge Gas Distribution • National Energy Board • Natural Resources Canada • Ontario Power Authority • Union Gas	Section 6
Energy Conversion Factors	• Enbridge Gas Distribution • National Energy Board • Statistics Canada • Union Gas	Section 5
GHG and CAC Emission Factors	• Environment Canada • Natural Resources Canada	Section 11

2.4.4 Input from Stakeholders and Industry

Stakeholders representing the federal and provincial governments, electricity and natural gas utilities, and industry participated in the study through an advisory committee. The committee discussed the study's methodology, implementation, progress, results and deliverables on a regular basis. It also reviewed and commented on the key deliverables.

To obtain input from industry about the challenges of and opportunities for advancing EM in Ontario industry, two workshops and one webinar were held. Forty-nine representatives participated in the workshops and webinar. The methodology and outcome of the consultation are discussed in Section 10.

3 DEFINITIONS



3 DEFINITIONS

This section defines concepts and elements that are essential to the study.

3.1 Energy Management

The EM potential analysis quantified the potential reduction in energy consumption due to EM actions. In this context, EM addresses energy consumption and not energy demand. Energy efficiency, an aspect of EM, includes technical and management best practices for reducing energy use and incorporates efficiency and conservation practices. To quantify associated GHG and CAC emission reduction, the savings were applied to on-site energy use for fuels and equivalent emissions for electricity generation.

3.2 Milestone Years

The EM potential analysis base year was 2007. Projected savings were assessed from 2007 to 2030, and results were provided for milestone years 2010, 2015, 2020 and 2025.

These milestone years align with various initiatives to reduce energy use and GHG emissions, such as the Ontario Power Authority's electricity peak reduction targets for 2010 and 2025[1] and the Canadian government's GHG emission reduction targets for 2020.[2]

3.3 Coverage of Energy Supply

The EM potential analysis addresses all forms of energy used by industry in Ontario according to the following energy supply categories: electricity, natural gas, refined petroleum products (RPP) and "other," which includes coal, coke, petroleum coke, coke oven gas, still gas, imported steam and biomass. The energy content conversion factors used are summarized in Appendix B.

3.4 Greenhouse Gas and Criteria Air Contaminants Emission Factors

The EM potential analysis includes an estimate of the potential reduction of GHG and CAC emissions. The GHG amounts are expressed in CO_2e. The CACs included are CO, NO_X, SO_X and particulate matter (PM). The GHG and CAC emission factors used in the study are summarized in Appendix B.

[1] Ontario Power Authority, *2008 Annual Report – On the Path to a Sustainable Electricity Future*. 2009.

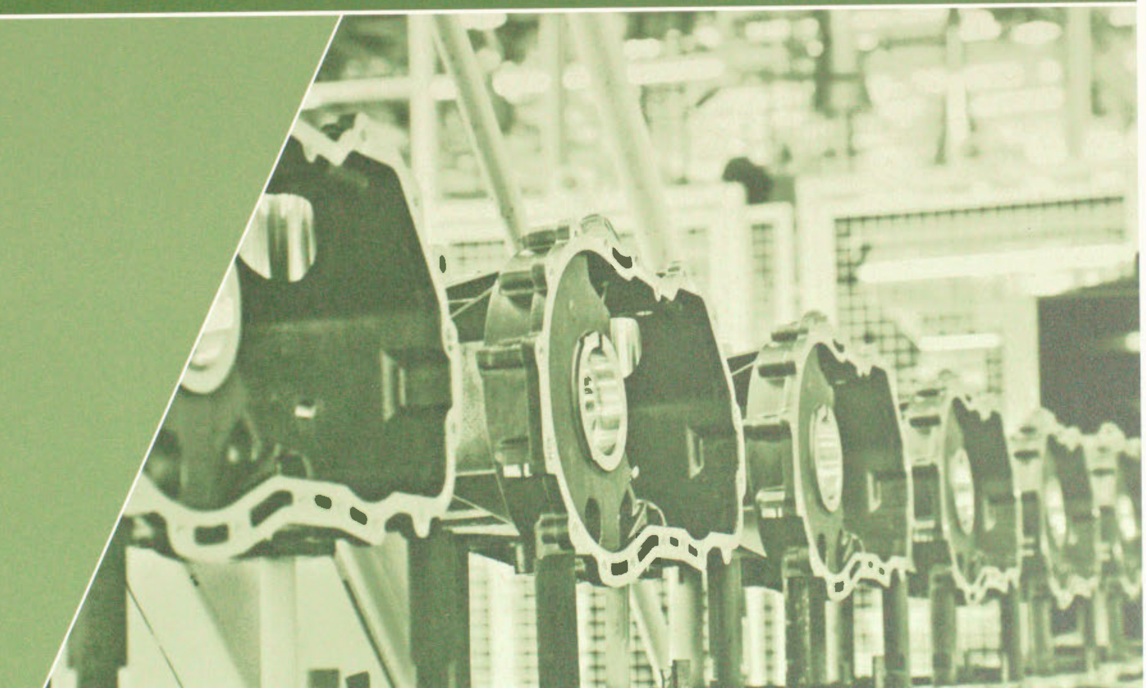
[2] Ministry of the Environment, *Regulatory Framework for Air Emissions*. 2007.

3.5 End Uses

The EM potential analysis assesses energy use for the following end uses:

- **Process Heating:** This end use includes all process heating systems and differentiates between indirect and direct heating end uses. Indirect heating systems use an intermediate heat transfer medium such as steam or hot water. Direct heating systems do not have an intermediate heat transfer medium, and the end uses include ovens, dryers, furnaces and kilns.
- **Process Cooling:** All process cooling and refrigeration systems are included in this end use, which includes cooling towers, freezers, chillers and associated refrigeration compressors.
- **Motive Power:** This end use includes all motive power equipment and is subdivided into compressed air systems, pumps, fans/blowers and all other motors. Other motors include conveyors, non-pneumatic metal-forming machines, saws and vibrating screens.
- **Electrochemical:** All chemical processes driven by electricity are included in this end use, including electroplating and electrolytic reduction of metals.
- **Process Specific:** All processes that use energy and are not included in the process heating, process cooling, motor driven, electrochemical and ventilation end uses are included in the process-specific end use (e.g., equipment that generates steam, such as paper-drying machines).
- **Heating, Ventilating and Air Conditioning:** Comfort heating and cooling systems are included in this end use, together with ventilation systems. Ventilation systems that are included can be associated with a process, such as the ventilation of paint booths, and/or with comfort, such as ventilation of air in a production area to maintain adequate air quality levels.
- **Lighting:** All indoor and outdoor lighting systems are included in this end use.
- **Other:** This end use includes all energy uses not included in any of the other categories listed above, such as propane or natural gas forklifts, battery chargers and automated doors.

4 SURVEY SAMPLE



4 SURVEY SAMPLE

4.1 Subsector Representation

The industrial sector was segmented into 11 subsectors using the NAICS. The NAICS is the accepted, standard methodology of classification in Canada and allows for consistency and accuracy in terms of references and use of secondary data; it groups together facilities with similar energy end-use profiles.

A total of 148 plants participated in the study. Six manufacturing subsectors had good representation: non-metallic mineral products (16 plants), transportation equipment and machinery (26), food and beverage (15), fabricated metal (26), plastics (18) and "other" (23).

Primary metal (8), chemical (8) and paper (6) had moderate representation. Petroleum and coal products manufacturing and mining (excluding oil and gas) had limited to no representation. To ensure that the potential energy reduction opportunity was accurately quantified with a representative model, the primary data for the subsectors with moderate to no representation were supplemented with secondary data.

4.2 Size of Facility

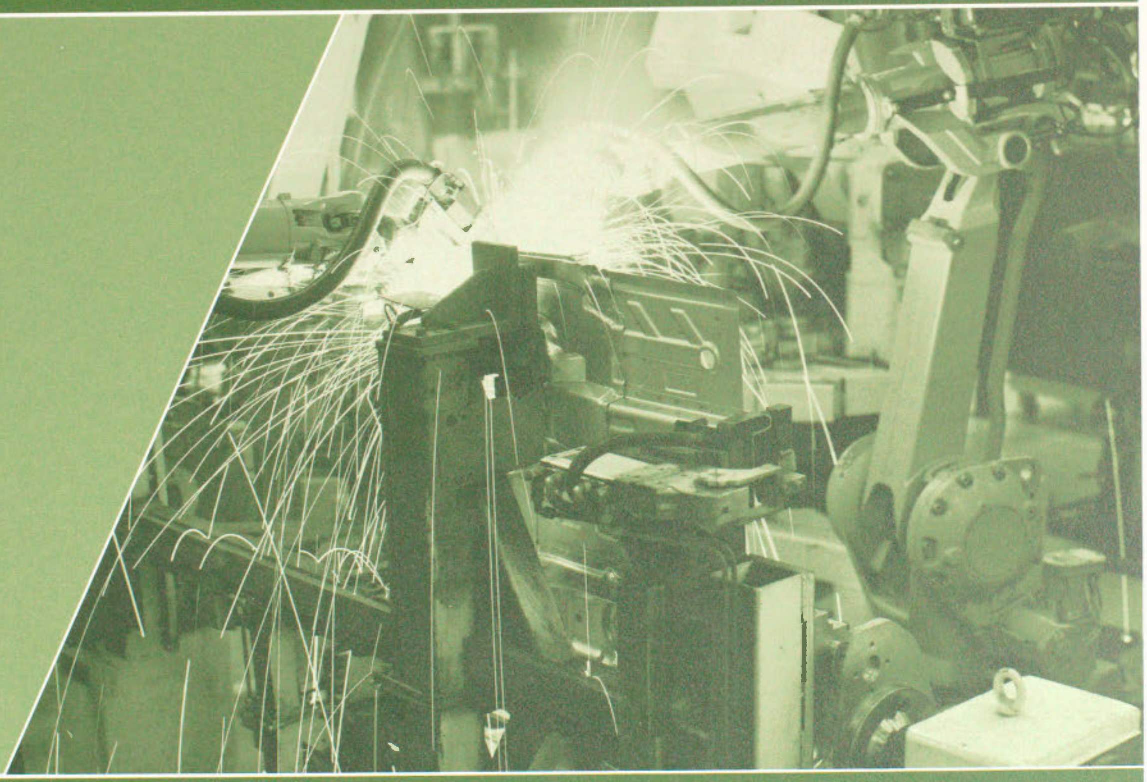
The facilities were classified according to size based on annual electricity or natural gas use, as summarized in Table 4-1. In this report, small and medium-size enterprises (SMEs) refer to all plants that are categorized as small and medium-size as per Table 4-1.

Table 4-1: Criteria for Size Classification Based on Annual Electricity or Natural Gas Use

Size (Number of Plants)	Electricity	Natural Gas
Small (35)	< 2 000 megawatt-hours (MWh)	< 50 000 m^3
Medium (53)	> 2 000 MWh < 20 000 MWh	> 50 000 m^3 < 500 000 m^3
Large (60)	> 20 000 MWh	> 500 000 m^3

5

2007 BASE YEAR ENERGY-USE PROFILE



5 2007 BASE YEAR ENERGY-USE PROFILE

The base year energy-use profile contains estimates of how Ontario industrial energy consumption is currently distributed by fuel type, subsector and end use.

5.1 Methodology

The 2007 base year energy-use profile by subsector was developed with a top-down approach. Total energy use was allocated proportionally to the end uses in each subsector and is based on data from Ontario Power Authority,[3] Union Gas,[4] Enbridge Gas Distribution[5] and Statistics Canada.[6] The proportional allocation of total energy use was based on a generic plant end-use profile, which is subsector-specific. Table 5-1 illustrates how a base year subsector energy-use profile was developed by disaggregating the total subsector energy use using a generic end-use profile.

Table 5-1: Sample Templates Illustrating Development of Subsector Energy-Use Profile

Total Primary Metal Manufacturing Energy Use for 2007 (PJ)					Generic Plant End-Use Profile (%)					Subsector Energy-Use Profile (GJ)			
Elec	NG	RPP	Other	End Use	Elec	NG	RPP	Other	End Use	Elec	NG	RPP	Other
22	37	9.3	84	Process Heat	36%	84%	85%	95%	Process Heat	8.1	31	7.9	79.0
				Cooling & Refrigeration	2%	0%	0%	0%	Cooling & Refrigeration	0.4	-	-	-
				Machine Drives	40%	0%	0%	0%	Machine Drives	9.0	-	-	-
				Electro-chemical	3%	0%	0%	0%	Electro-chemical	0.7	-	-	-
				Process Specific	6%	11%	0%	5%	Process Specific	1.3	4.1	-	4.2
				HVAC	8%	4%	0%	0%	HVAC	1.8	1.5	-	-
				Lighting	4%	0%	0%	0%	Lighting	1.0	-	-	-
				Other	1%	1%	15%	0%	Other	0.2	0.4	1.4	-

[3] Ontario Power Authority. *MIF Industrial Forecast by Sub-sector for CME*. 2009.

[4] Marbek. *Natural Gas Energy Efficiency Potential Analysis – Industrial Sector, for Union Gas*. 2009.

[5] Marbek. *Natural Gas Energy Efficiency Potential: Update 2008, for Enbridge Gas Distribution*. 2009.

[6] Statistics Canada. *Report on Energy Supply and Demand in Canada 2007*. 2009.

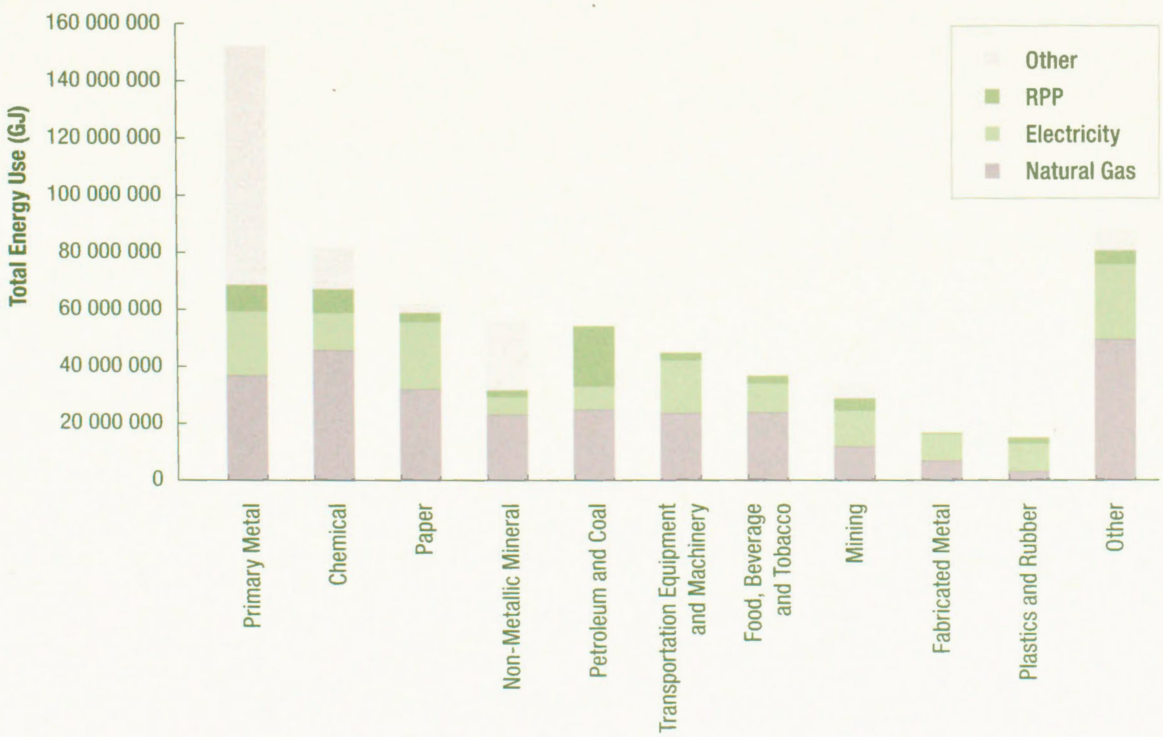
The Ontario subsector-specific generic plant profiles were developed using the following steps:

- A **draft profile** was constructed using weighted averages of the energy balances developed for each of the 148 participating plants. The draft profiles for the two subsectors with limited to no participation (i.e., the petroleum and coal product manufacturing and mining subsectors) were developed from secondary data sources, listed in Section 12.1.
- The profiles were **reviewed** by Ontario industrial experts and compared with the project team's primary data from other studies and information from the secondary data sources.
- Based on the review of the draft profiles, **minor adjustments** were made to the profiles to ensure that the generic plant profiles were representative of the Ontario subsectors.

5.2 2007 Base Year Energy Use by Subsector

In 2007, Ontario's industrial sector used an estimated total of 732 PJ of energy (one petajoule (PJ) = 2.8 x 10^5 MWh). Natural gas accounted for 38 percent of total energy use; electricity, 22 percent; biomass, 13 percent; RPP, 8 percent; and "other," 19 percent. Given that the focus of this study is to advance opportunities in EM and reduce GHG and CAC emissions, biomass (used mainly in the paper and wood products industry) was excluded from the energy efficiency potential analysis. The total annual industrial energy use excluding biomass was 640 PJ. Energy use by subsector is shown in Figure 5-1. The 10 largest subsectors, by total energy use, accounted for close to 85 percent of Ontario industrial energy use.

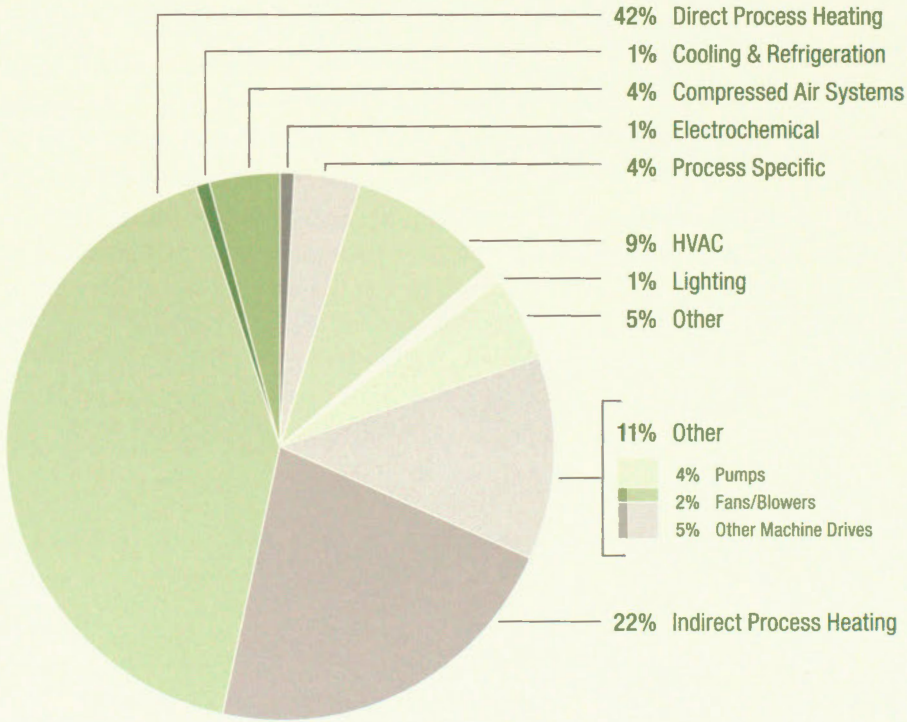
Figure 5-1: 2007 Base Year Energy Use by Subsector (Excluding Biomass)



5.3 Energy Use by End Use

The 2007 base year for energy use by end use for the entire industrial sector is shown in Figure 5-2. Close to 65 percent of the energy was used by industry for process heating, while motive power and air compressors accounted for close to 15 percent.

Figure 5-2: 2007 Base Year Total Industry Energy Use by End Use (PJ)



6 REFERENCE CASE

6 REFERENCE CASE

Developing the reference case was the second step in the EM potential analysis. The reference case provides a projection of energy use to 2030 in the absence of any new EM market interventions after 2007 (i.e., incremental to what utilities and government have already planned for this period). The reference case is the baseline against which the scenario of energy savings is calculated.

6.1 Methodology

The study did not include the development of energy-use forecasts. Instead, existing forecasts were used to determine the projected energy use in the reference case. Energy use growth rates were determined for each subsector from 2007 to 2010 and in five-year increments from 2010 to 2030. The three main sources used to develop the reference case energy-use profiles were the following:

- Updated Ontario Power Authority electricity use forecast data for the industrial sector,[7] which show decreasing industrial load between 2005 and 2008; recovery was anticipated to begin in 2010. Observed industrial electricity load in 2009 was significantly lower than that anticipated in the forecast. At this time, the nature and timing of economic recovery is uncertain;
- The latest energy use demand and supply forecast from the National Energy Board (NEB),[8] which also reflects the economic downturn. The forecast is only applicable to 2020.
- Previous NEB forecast data,[9] which were used to inform the forecast from 2020 to 2030.

The following additional assumptions and approaches pertain to the development of the reference case:

- Unlike the Ontario Power Authority electricity growth rates, the NEB energy use growth rates are not provided at the **subsector level**. To develop the growth rates for natural gas, refined petroleum products and other fuels, growth rates similar to the electricity growth rates were calibrated and applied to the NEB total Ontario industry growth rates for each fuel.
- The Ontario Power Authority and NEB forecasts, and by association the reference case scenario, incorporate an estimate of "**natural conservation**," i.e., changes in end-use efficiency over the study period that are projected to occur in the absence of new market interventions.
- The base year **end use profiles**, in terms of proportional energy use by each end use, were frozen for the duration of the reference case. This means, for example, that the percentage of natural gas use in 2007 in the food and beverage subsector allocated to boilers remains constant from 2007 to 2030.

[7] Ontario Power Authority. *MIF Industrial Forecast by Sub-sector for CME.* 2009.

[8] National Energy Board. *2009 Reference Case Scenario: Canadian Energy Demand and Supply to 2020 – An Energy Market Assessment, July 2009.*

[9] National Energy Board. *Canada's Energy Future: Reference Case Scenario to 2030 – An Energy Market Assessment, November 2007.*

6.2 Energy Use Growth Rates

The weighted average percentage growth rates for each energy source are summarized in Table 6-1. The growth rates are dependent on the economic drivers assumed in the NEB and Ontario Power Authority forecasts.

Table 6-1: Weighted Average Growth Rate by Energy Source

Fuel Type	Percentage Overall Growth Rate in Period				
	2007 to 2010	2010 to 2015	2015 to 2020	2020 to 2025	2025 to 2030
Natural Gas	-14.2%	14.5%	-1.5%	8.7%	8.7%
Electricity	-3.8%	5.3%	2.5%	2.6%	3.0%
RPP	0.8%	10.9%	4.1%	13.9%	11.0%
Other	-2.6%	18.9%	-10.3%	4.6%	3.9%

6.3 Reference Case Energy Use

It is estimated that the reference case total energy use increased by about 16 percent from 2007 to 2030. In absolute terms, the increase is close to 104 PJ. The largest increases in energy use are associated with four of the five largest subsectors by energy use: primary metal, chemical, non-metallic mineral products, and petroleum and coal products manufacturing. The "other industry" manufacturing subsector shows the largest decrease in energy use, and the remaining subsectors each show less than a 10 percent change in energy use over the 23-year period.

7

ENERGY EFFICIENCY AND CONSERVATION BEST PRACTICES

7 ENERGY EFFICIENCY AND CONSERVATION BEST PRACTICES

7.1 Methodology

Industrial energy efficiency and conservation best practices were identified using secondary sources and the consulting firm's extensive databases, which were developed with input from many industrial experts. The secondary sources include literature, equipment suppliers and industry EM experts.

The following additional approaches were used to define the TBP:

- Only technically feasible and commercially available TBPs are included in the analysis;
- TBPs are included at a level of detail that is manageable within the budget and scope of the study. This necessitates that the TBPs include a degree of bundling. For example, the TBP "economizers" for steam boilers include standard and condensing economizers;
- The list of TBPs was refined and finalized with input from the study's advisory committee.

The technology profiles were developed for each TBP in order to provide required input parameters for the energy efficiency potential analysis modelling. The technology profiles are included in Appendix D. Secondary sources and the consultant's extensive databases were used to derive the necessary input parameters for the TBPs, which include capital costs, operating and maintenance costs, life of the best practice, also referred to as the "measure life," and energy savings of the best practice.

The MBP model was developed by using various similar studies and expanded by using the experience acquired from previous applications. The EM models that contributed significantly to the definition of the MBP model are the EM models developed by Natural Resources Canada's Office of Energy Efficiency, UK Carbon Trust, U.S. Energy Star and Australia's Environmental Protection Authority Victoria. Energy performance at a plant is affected by the MBPs implemented at both the corporate and plant levels. MBPs applicable to the corporate level and the plant level were identified and included in the study.

7.2 Technical Best Practices

TBPs are production systems, pieces of equipment, methods and practices that result in advanced levels of energy user performance. Examples range from submetering and integrated control systems to insulation and high-efficiency dryers. Technology profiles with descriptions are included in Appendix D-2.

7.3 Management Best Practices

MPBs refer to the management practices that improve energy use performance. The MBPs are included in Appendix D-1 and are categorized as follows:

- **Policy and Planning.** Effective management starts with the publication and distribution of a policy statement that commits the organization to EM. Effective planning is characterized by strong links to the energy policy and by the treatment of energy as a strategic rather than an operational issue. Appropriate EM plans are in place that link responsibilities, tasks, performance indicators and results.
- **Organization and Accountability.** Competencies and organizational structure are required for efficient operation, maintenance, promotion and management of energy systems, action plans and equipment. Organization refers to the organization of people, allocation of EM responsibilities and integration with other areas of management and other functions.
- **Financing.** Financing must be available to identify, develop and implement EM. Financing includes developing the business case for EM projects and financial planning that integrates EM.
- **Project Management.** Identification, development and implementation of energy efficiency opportunities ensure that EM produces results. Project development and management requires knowledge, the capacity to identify and assess opportunities, and management skills to implement projects.
- **Monitoring.** Monitoring is the process of gathering, recording, analysing and reporting data and putting it to use constructively (e.g., in areas such as training), as well as monitoring and measuring management and technical energy performance in order to be able to take action to meet identified EM priorities.
- **Reporting and Communication.** Proactive reporting, communication and promotion, both internally and externally, help to build and sustain awareness of EM and its impacts, encourage input from employees in regard to savings opportunities, provide feedback on needs and achievements, and establish corporate responsibility.
- **Training and Capacity Building.** Developing capacity enables EM to be implemented and continuously improved. Knowledge gaps must be identified and a training and capacity-building plan implemented to ensure that personnel have adequate knowledge.

8 BASE YEAR IMPLEMENTATION OF BEST PRACTICES

8 BASE YEAR IMPLEMENTATION OF BEST PRACTICES

8.1 Methodology

The extent to which best practices are currently implemented in industry (also referred to as the market penetration rate) was determined through use of an energy performance benchmarking approach. For each best practice, the results from the benchmarking assessment provided information for determining the base year market penetration rate and the remaining potential for increased implementation.

A total of 148 plants participated in the energy performance benchmarking surveys; 56 surveys included on-site assessments. A scoring system was used to convert the information submitted by the plants in the TBP and MBP surveys into implementation rates. For example, the response to each TBP and MBP was given a score using the following system:

- applicable TBP implemented in facility (yes): score = 1
- applicable TBP not employed (no): score = 0

In cases where the best practices could be partially implemented, a three-level scoring system was used. A total score was calculated and each practice received an equal weight. For the TBPs, the scores were determined for each end use of energy at the facility level, and the scores were further aggregated for the entire subsector. The MBP scores were similarly determined at the category and subsector levels.

A draft set of market penetration rates was constructed from the benchmarking results. For the two subsectors with limited to no participation, the penetration rates were developed from the project team's databases and the secondary data sources listed in Section 13. The draft market penetration rates were reviewed by Ontario industrial technical experts and compared with the project team's data from other studies and information from the secondary data sources. Based on this review, minor adjustments were made to ensure that the penetration rates were representative of the Ontario subsectors.

8.2 Surveyed Implementation of Technical Best Practices

8.2.1 Surveyed Implementation of Technical Best Practices – All Participants

The implementation of TBPs in Ontario industry by subsector is shown in Figure 8-1 and by end use in Figure 8-2. For the two subsectors with limited to no participation, no benchmarking results are included.

The results include the median and the 25th and 75th percentile values. At the median, 50 percent of the plants have values lower than the specified value. The 75th percentile is generally selected as the benchmark energy performance value for plants to strive for. This means that 75 percent of the plants have values below the benchmark; the top quartile is the target for companies to achieve.

The results show that the implementation of TBPs in the Ontario industrial sector is relatively low. The 75th percentile range is between 31 and 42 percent. This means that most of the plants have implemented less than 42 percent of applicable TBPs and that there is potential for most companies to implement more than 58 percent of the TBPs.

Compressed air systems have the greatest potential to increase implementation of TBPs for all end uses, especially for electricity end uses, such as motive power, cooling and refrigeration. Compressed air systems have the highest rate of implementation of TBPs.

Figure 8-1: Implementation of TBPs by Subsector

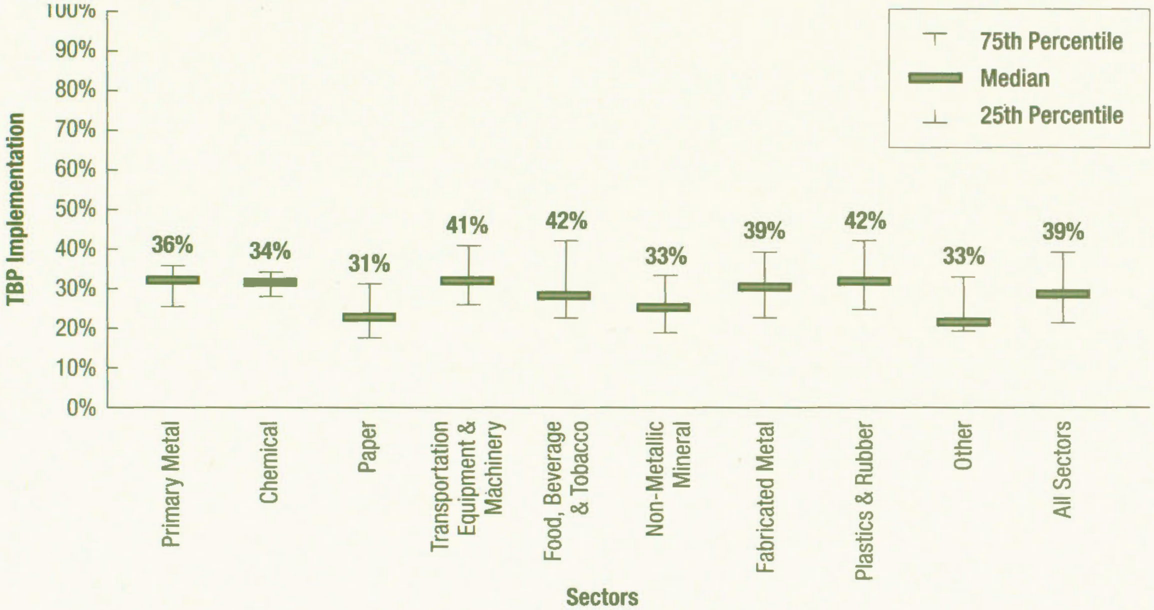
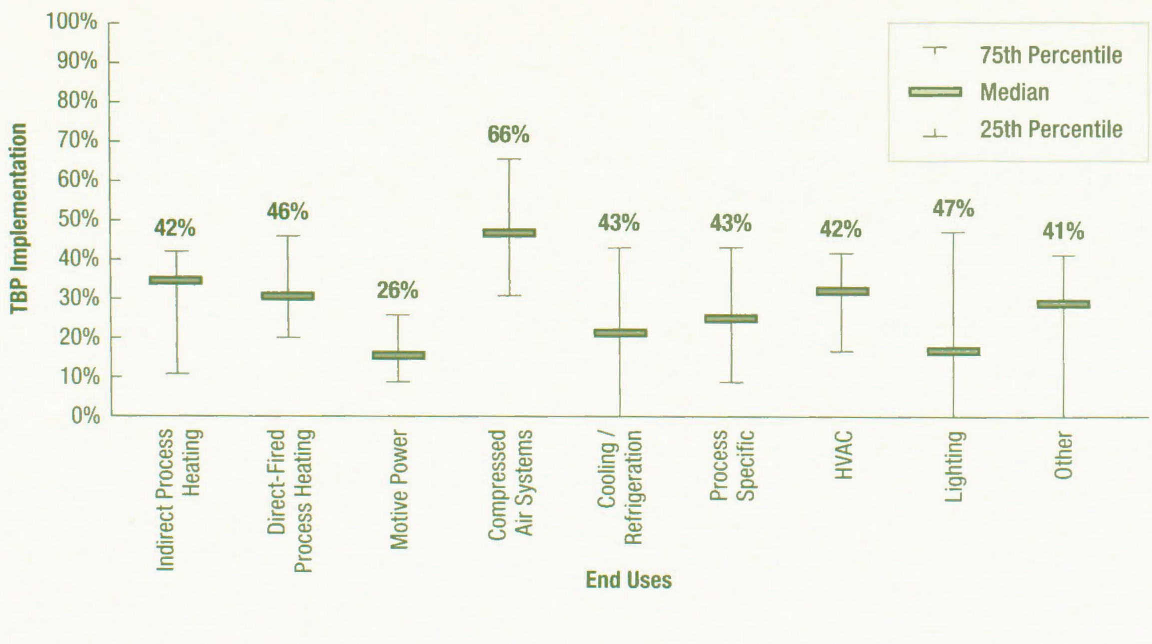


Figure 8-2: Implementation of TBPs by End Use



8.2.2 Surveyed Implementation of Technical Best Practices – Large Plants vs Small and Medium-size Enterprises

The implementation of TBPs in Ontario industry by end use for all large plants is shown in Figure 8-3, while the implementation of TBPs by small and SMEs is shown in Figure 8-4. For a definition of large plants and SMEs, see Section 4.2.

Figure 8-3: Implementation of TBPs by Large Plants

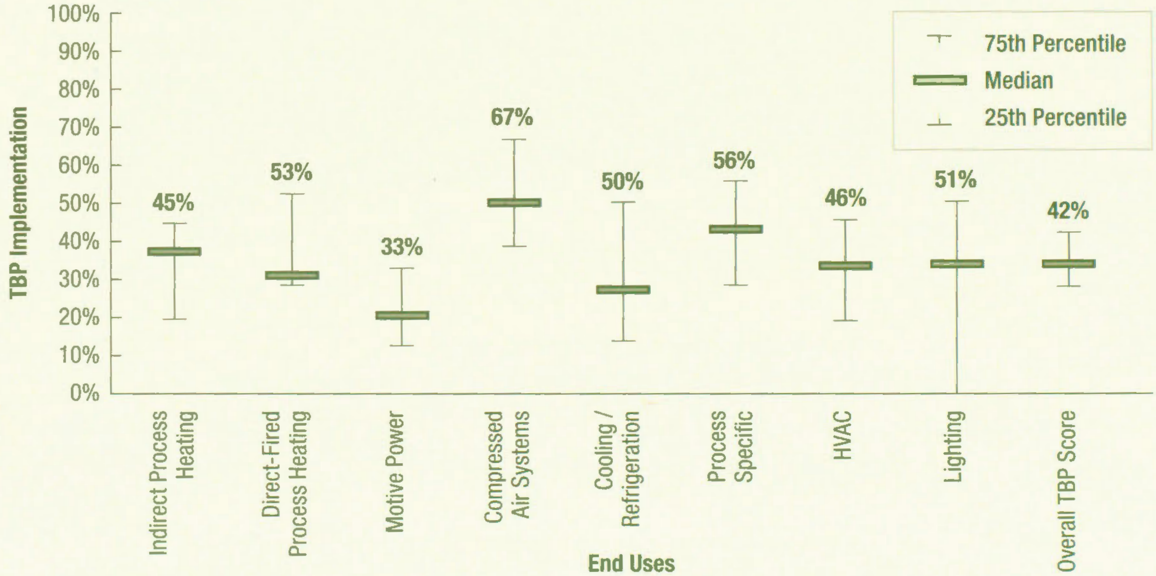
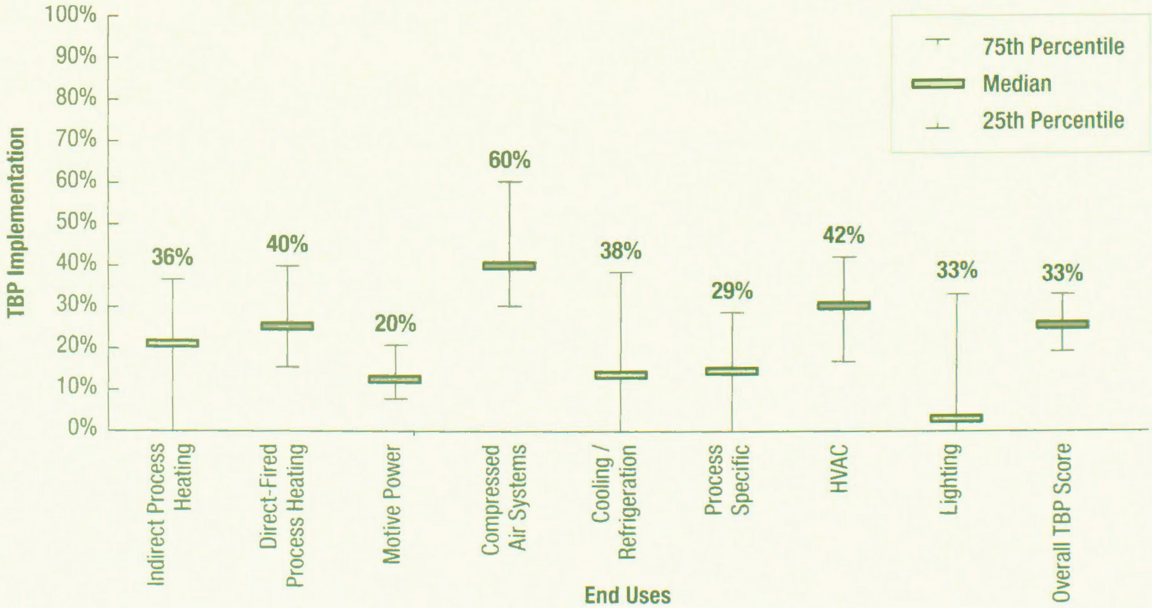


Figure 8-4: Implementation of TBPs by SMEs



On average, large plants have implemented nearly 10 percent more TBPs than have SMEs. The most significant differences in TBP implementation were found for the following end uses:

- **Lighting** – About 50 percent of large plants have implemented more than 33 percent of the best practices; the median value for SMEs is 3 percent.
- **Process specific** – About 50 percent of large plants have implemented more than 43 percent of the best practices; the median value for SMEs is 14 percent.
- **Indirect process heating** – About 50 percent of large plants have implemented more than 37 percent of the best practices; the median value for SMEs is 21 percent.

8.3 Surveyed Implementation of Management Best Practices

8.3.1 Surveyed Implementation of Management Best Practices – All Participants

The implementation of MBPs in Ontario industry by subsector is shown in Figure 8-5 and by MBP category in Figure 8-6. For the two subsectors with limited to no participation, no benchmarking results are included.

Among the subsectors, the benchmarking results indicate a relatively large difference in the extent to which MBPs are implemented. Overall, 75 percent of plants have implemented less than 48 percent of the MBPs, and the potential exists to implement the remaining 52 percent of MBPs.

Figure 8-5: Implementation of MBPs by Subsector

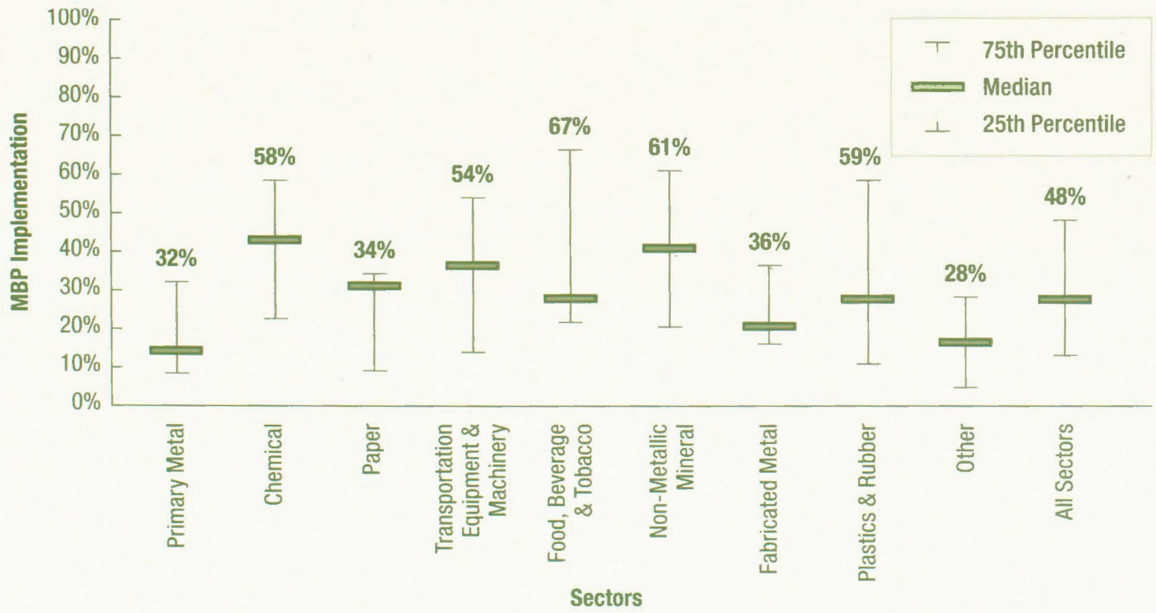
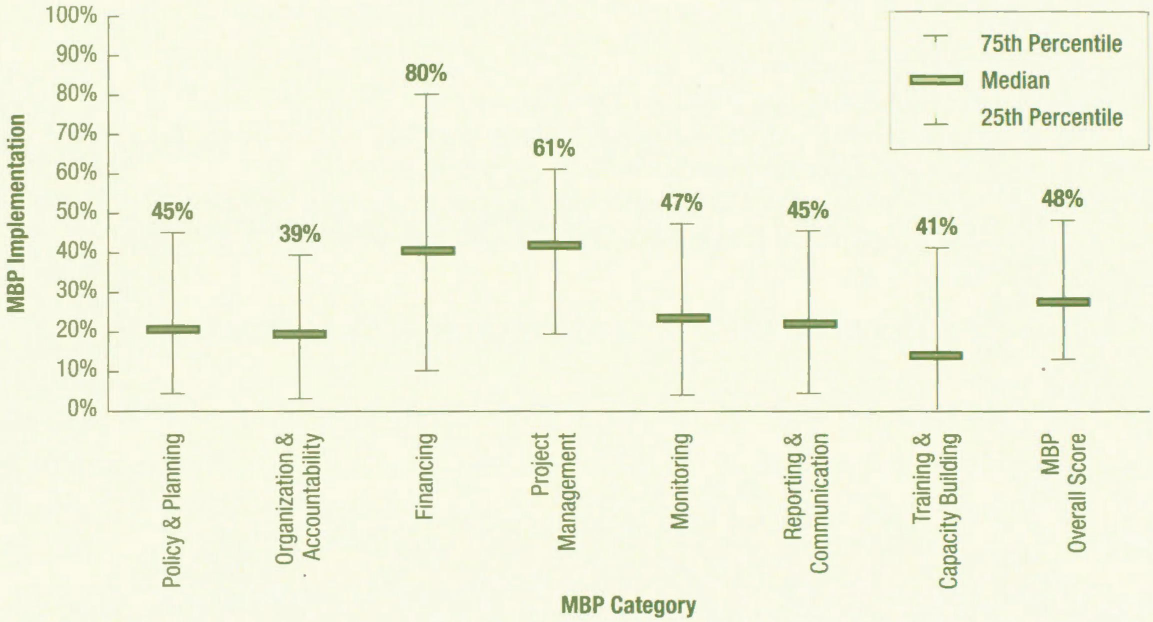


Figure 8-6: Implementation of MBPs by Category



In Figure 8-6, the MBP categories are listed in the sequence that a company would likely follow to implement best practices according to a management plan or management standard. The results show that, in general, plants manage and finance energy projects on an ad hoc basis. Best practices associated with continuous improvement are not widely implemented, as shown by the categories with lowest implementation of MBPs:

- policy and planning
- organization and accountability
- monitoring
- reporting and communication
- training and capacity building

8.3.2 Surveyed Implementation of Management Best Practices — Large Plants vs Small and Medium-size Enterprises

The implementation of MBPs in Ontario industry by category for all large plants is shown in Figure 8-7, while the implementation of MBPs by SMEs is shown in Figure 8-8. The implementation of MBPs by plant size indicates that large plants have implemented an average of nearly 30 percent more MBPs than have SMEs. The most significant differences in MBP implementation were found in the following categories:

- **Financing** – 50 percent of large plants have implemented more than 70 percent of the best practices; the median value for SMEs is 20 percent.
- **Policy and Planning** – 50 percent of large plants have implemented more than 42 percent of the best practices; the median value for SMEs is 7 percent.
- **Monitoring** – 50 percent of large plants have implemented more than 46 percent of the best practices; the median value for SMEs is 12 percent.

Figure 8-7: Implementation of MBPs by Large Plants

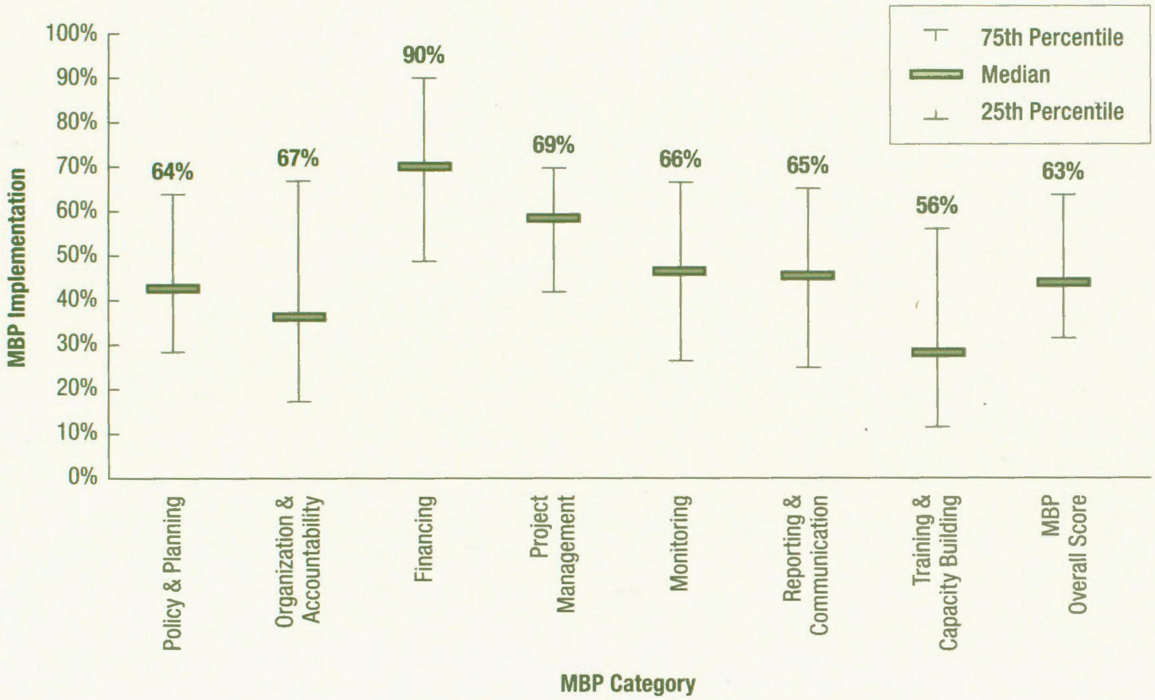
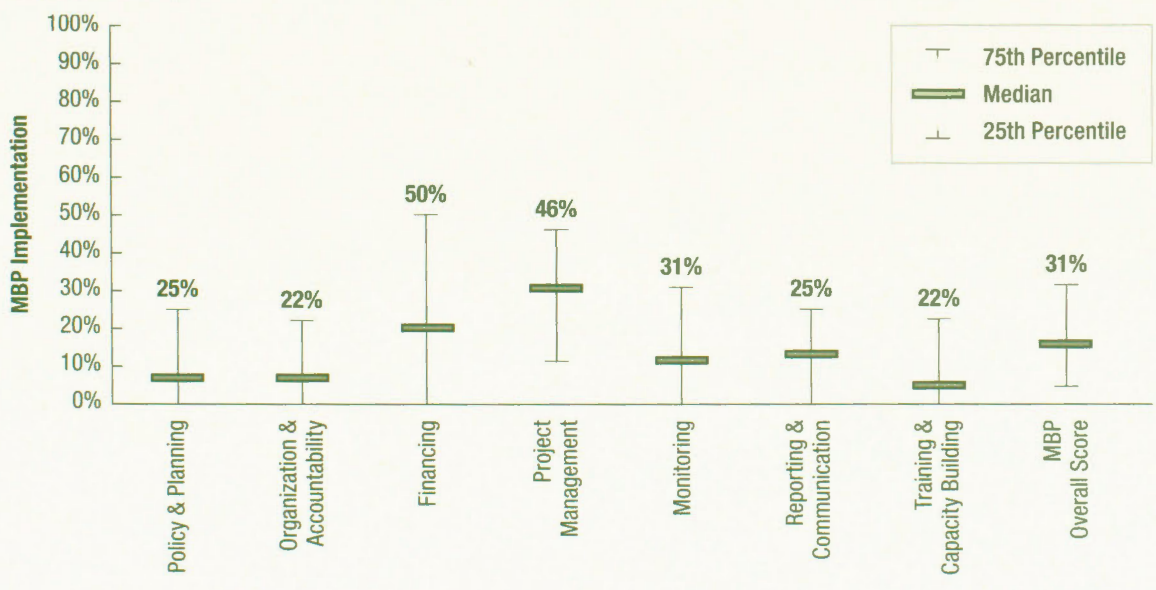


Figure 8-8: Implementation of MBPs by SMEs



8.4 Relationship Between Technical Best Practice and Management Best Practice Implementation

The higher the degree of MBP implementation, the higher the degree of TBP implementation. Plants are grouped into four quartiles based on the number of MBPs implemented. For example, a plant that has implemented more than 75 percent of the MBPs is in the top quartile (75 to 100 percent). Averaging TBP scores for all plants in each MBP quartile shows that plants that have implemented more than 75 percent of the MBPs have, on average, implemented 42 percent of the applicable TBPs. Only 5 percent of all plants fall into this top MBP quartile category.

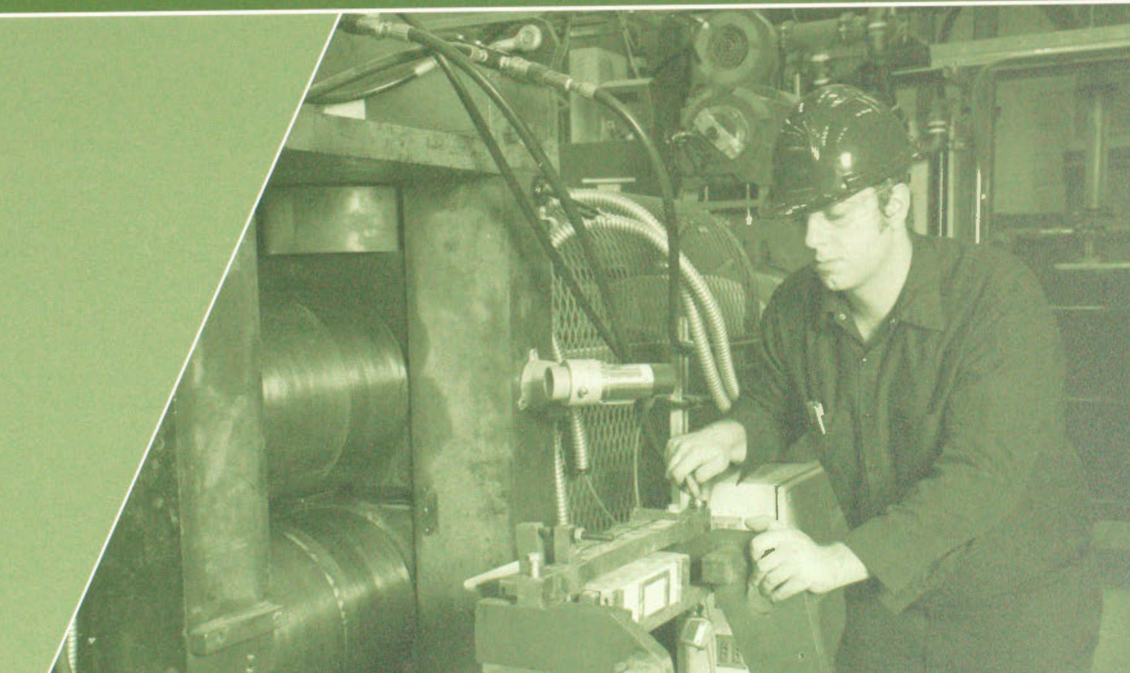
By comparison, plants that have implemented less than 25 percent of the MBPs have, on average, implemented 25 percent of the applicable TBPs. Almost 50 percent of all plants fall into this bottom MBP quartile category.

8.5 Overall Implementation of Technical Best Practices and Management Best Practices by Large and Small and Medium-size Enterprises Plants

The results indicate that 22 percent of the plants have implemented more than 40 percent of the TBPs and that the majority of these plants (63 percent) are large plants. There is considerable potential for SMEs to increase the implementation of TBPs.

Three quarters of the plants that have implemented more than 50 percent of the MBPs are large plants. SME plants account for 70 percent of the plants that have implemented less than 50 percent of the MBPs. This indicates a significant potential for SMEs to increase the implementation of MBPs.

9 ECONOMIC POTENTIAL SCENARIO



9 ECONOMIC POTENTIAL SCENARIO

9.1 Methodology

The TRC test was used to determine the economic feasibility of the TBPs. This test measures the change in the TRCs to society, excluding externalities, due to the implementation of an energy management measure.[10] The TRC test generates a net present value (NPV) that sums the streams of benefits and costs over the lifetime of the equipment or technology. It uses a discount rate to express these streams as a single "current year" value. If the net present value is positive, i.e., benefits exceed costs, the EM measure is considered cost-effective from a societal perspective. Further details on the total resource cost formula and input parameters are provided in Appendix A.

There are two groups of TBPs: replacement and retrofit. Replacement TBPs, which are implemented at the end of the equipment's useful life, were modelled using natural stock turnover rates. Retrofit TBPs, which can be added to equipment or to the plant process at any time, were modelled based on implementing the retrofit technology in the first study milestone year.

Energy use within each of the subsectors was modelled with the same energy models used to generate the reference case. The MBPs were applied as one bundle, referred to as "energy management," to the system end use, which is the total plant energy use. Individual TBP savings were broken down, with each TBP saving a percentage of the remaining energy in an end use. The absolute energy savings were calculated as the difference between the energy consumed in the reference case and in the economic potential scenario.

9.2 Economic Potential Scenario Energy Use

If all of the economically feasible best practices are implemented, the total Ontario industrial energy use will drop by an estimated 110 PJ from 2007 to 2030. In other words, estimated energy use in 2030 will be 29 percent less than the energy use in the reference case.

Estimated energy use and savings by industry are summarized by subsector, fuel type and end use in Table 9-1, Table 9-2 and Table 9-3, respectively.

The economic potential energy savings per subsector in 2030 ranges from 25 percent to 36 percent (when compared with reference case energy use). The absolute energy savings are greater for subsectors that account for the largest share of energy use, while lower absolute energy savings are associated with subsectors that account for a smaller share of total energy use.

[10] Adapted from the Ontario Energy Board's Total Resource Cost Test Manual, 2005.

Table 9-1: Reference Case and Economic Potential Scenario of Energy Use by Subsector (PJ)

	Base Year	Reference Case	Economic Potential	2030 Economic Potential Savings	
Subsector	**2007**	**2030**	**2030**	**PJ**	**%**
Primary Metal Manufacturing	152	200	147	53.0	27%
Chemical Manufacturing	82	104	78	26.0	25%
Paper Manufacturing	62	64	45	19.0	30%
Non-Metallic Mineral Product Mfg.	55	79	54	24.0	31%
Petroleum and Coal Products Mfg.	54	74	52	23.0	30%
Transportation Equipment & Machinery Mfg.	45	41	28	13.0	32%
Food, Beverage and Tobacco Product Mfg.	37	33	23	10.0	31%
Mining (Excl. Oil & Gas)	33	35	26	10.0	27%
Fabricated Metal Product Mfg.	17	16	10	5.8	36%
Plastics and Rubber Manufacturing	15	20	14	6.0	30%
Other Manufacturing	87	78	53	24.0	31%
Total	**640**	**744**	**530**	**214**	**29%**

Natural gas accounts for an estimated 50 percent of the total 2030 industry savings—largely because of the significant savings potential estimated for direct and indirect process heating end uses. The "system" end use, which includes measures that apply to the total plant, accounts for over 35 percent of all economic potential savings by 2030.

Table 9-2: Reference Case and Economic Potential Scenario of Energy Use by Energy Source (PJ)

	Base Year	Reference Case	Economic Potential	2030 Economic Potential Savings	
Energy Source	**2007**	**2030**	**2030**	**PJ**	**%**
Natural Gas	282.0	323.0	216.0	106.0	33%
Electricity	158.0	176.0	124.0	52.4	30%
RPP	62.5	91.4	68.7	22.7	25%
Other	137.0	154.0	121.0	32.7	21%
Total	**640**	**744**	**530**	**214**	**29%**

Table 9-3: 2030 Economic Potential Scenario of Energy Savings by End Use (PJ)

	2030 Economic Potential Savings	Savings as Percentage of Total
End Use	**PJ**	**%**
System	75.0	31.0%
Indirect Process Heating	22.0	12.0%
Direct Process Heating	72.0	30.0%
Cooling & Refrigeration	1.0	0.6%
Motive Power	21.0	14.0%
Electrochemical	0.3	0.1%
Process Specific	2.7	0.5%
HVAC	19.0	11.0%
Lighting	1.3	0.7%
Total	**214**	**100%**

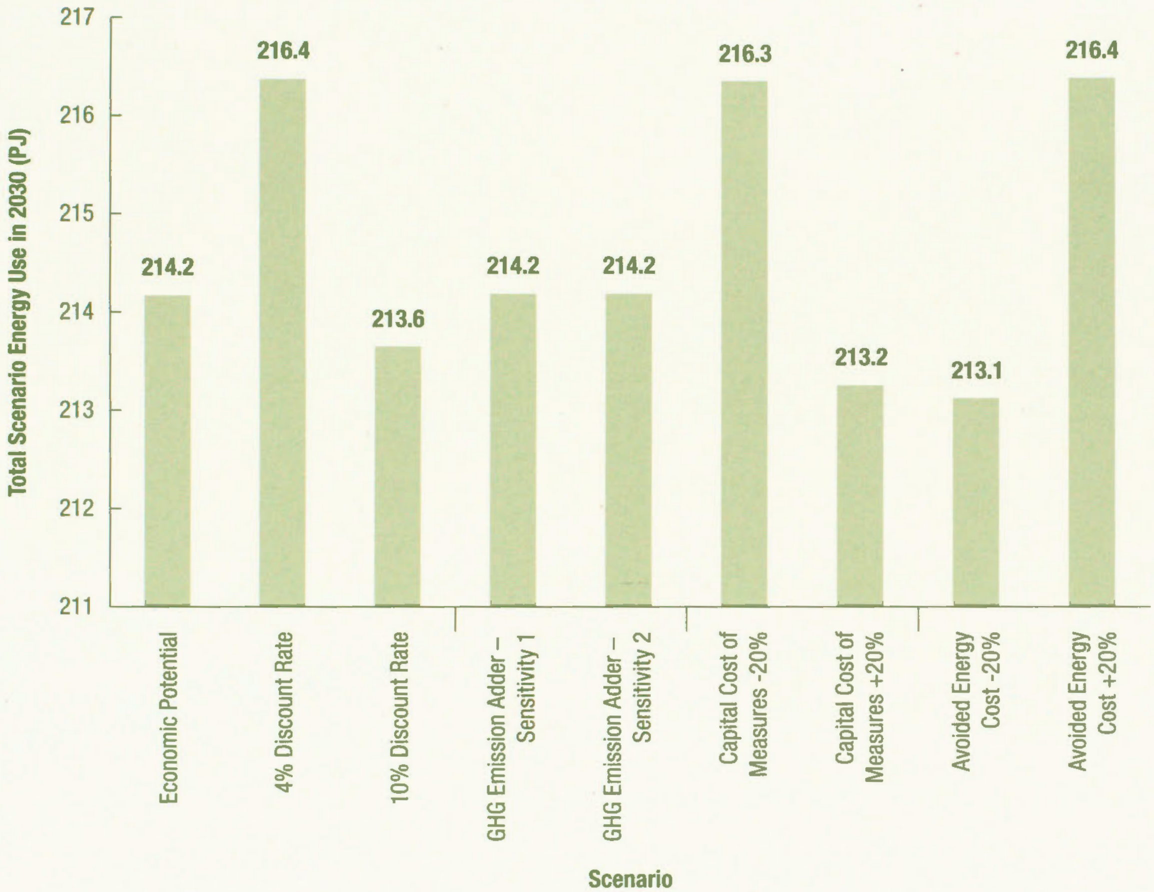
9.3 Sensitivity Analysis

A sensitivity analysis was conducted to determine the impact on the economic potential of changes in the following inputs:

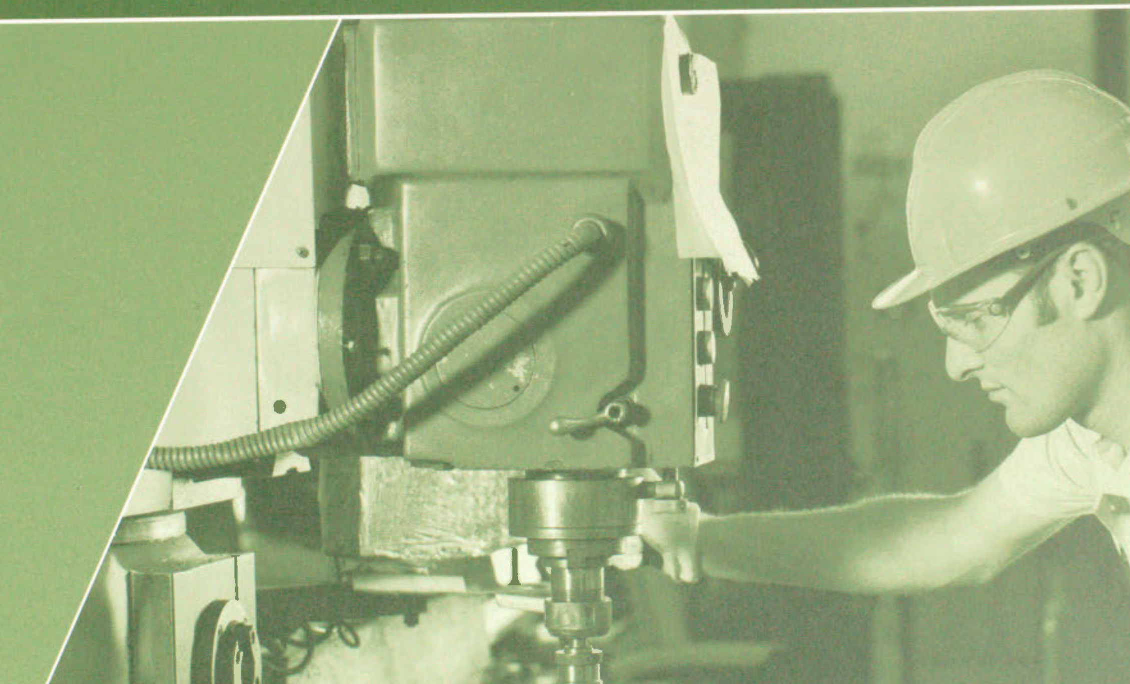
- **Discount rate:** Changed from 8 percent to 4 percent and 10 percent.
- **GHG emission adder:**
  - Sensitivity 1: The cost of an opportunity included a carbon adder of $15 per tonne from 2012 to 2015. From 2016 to 2020, the adder was increased to $45 per tonne; from 2020 to the end of the study period, the adder was increased to $71 per tonne;
  - Sensitivity 2: The cost of an opportunity included a carbon adder of $24 per tonne from 2012 to the end of the study period.
- **Capital cost of energy efficiency measure:** Decreased by 20 percent and increased by 20 percent.
- **Avoided electricity and fuel cost:** Decreased by 20 percent and increased by 20 percent.

As shown in Figure 9-1, the change in the economic potential savings due to a change in the above-mentioned variables is less than 1 percent. A 20 percent increase or decrease in the avoided electricity and fuel cost has the biggest impact on economic potential. A 20 percent increase in avoided cost will increase the economic potential savings by 1.0 percent, while a 20 percent decrease in avoided cost will reduce the economic potential savings by 0.5 percent in 2030. Adding a carbon price has an insignificant impact on the economic potential scenario.

Figure 9-1: Economic Potential Sensitivity Analysis of Energy Savings in 2030 (PJ)



10 BEST PRACTICES IMPLEMENTATION: CHALLENGES, BARRIERS AND PROGRAM CONCEPTS



10 BEST PRACTICES IMPLEMENTATION: CHALLENGES, BARRIERS AND PROGRAM CONCEPTS

It is necessary to understand the challenges facing industry in order to increase the implementation of best practices. Programs and policies can be designed to address these challenges. The previous sections identified and quantified the energy savings opportunities, while this section identifies the challenges and potential program concepts or solutions. The challenges and solutions provide the necessary information for developing an action plan that industry can use to advance EM.

10.1 Methodology

Facilitated workshops were conducted to obtain input from industry and stakeholders. Two face-to-face workshops and one webinar were organized, and a total of 49 representatives participated. Industry representatives accounted for close to 90 percent of the 49 representatives; the remaining 10 percent included representatives from utilities, government and energy service providers.

The questions asked of workshop participants were organized so that both barriers and solutions were discussed and rated according to five strategic categories forming a "continuum of continuous improvement" required to generate and sustain better energy use performance and reduce associated GHG emissions in industry. In this continuum, shown below, the ultimate outcome is sustained results in transformation of the market at the market, corporate and facility levels.

Corporate Practices → Opportunity Assessment → Taking Action → Results and Market Transformation

The workshop facilitators used a list of 37 typical challenges and 26 program concepts. The challenges and program concepts can be classified in five categories. Table 10-1 explains the relevance of these categories of challenges and solutions.

Table 10-1: Categories of Challenges and Solutions

Challenge and Solution Category	Path of Continuous Improvement
Commitment to Energy Management	This is perhaps the most critical corporate practice required for successful and sustained energy use performance improvements. Workshop participants were asked to comment on aspects of senior management commitment, organizational structure and accountabilities in support of EM.
Knowledge of Energy Efficiency (EE) Opportunities	This refers to the various aspects of knowledge and capacity needed to develop a defensible EM opportunity assessment. Operations and management (O&M) and capital expenditure business case opportunities can be generated and sustained. Workshop participants were asked to comment on their knowledge of EE opportunities, their understanding of the benefits (cost and co-benefits) that result from EE opportunities and their understanding of how to assess the technical and economic feasibility of EE opportunities.
Transaction Costs	This refers to the "hassle" factor, i.e., the time and effort required to become informed about EM opportunities and implementation. The way in which companies deal with transaction costs affects the undertaking of opportunity assessments and the implementation of EM measures. Workshop participants were asked to comment on various aspects of the "hassle" factor associated with developing EM projects, such as the effort it takes to become informed about EE opportunities and products and about funding and incentives.
Financing of EE Projects	This refers to the various aspects of securing internal and external financing in support of developing an EM business case (e.g., paying for feasibility studies) and implementing EM measures. The way in which companies deal with EM financing also affects the successful undertaking of opportunity assessments and the implementation of EM measures. Workshop participants were asked to comment on issues related to making business cases for EE projects, accessing business cases and project funding internally and externally, and achieving company hurdle rates.
Product and Service Availability	EM product and service availability, choice and quality affect ease of implementation and the degree of success in taking action and achieving desired results and market transformation. Workshop participants were asked to comment on the availability and quality of products, services and EM service providers.

Representatives were asked to identify any additional challenges and program concepts that had not been included on the list. No new challenges or solutions were added to the list, and representatives viewed it as comprehensive. In facilitated activities and group discussions, the representatives submitted individual scores for the challenges and program concepts. The scores from all representatives were added together to determine an overall percentage score and a prioritized ranking of the challenges and program concepts.

10.2 Challenges and Solutions Relative to the Implementation of Best Practices

10.2.1 Challenge Compilation Results

The top 15 challenges, in descending order of importance, are listed in Table 10-2. Taken as a whole, this set of challenges means that investments by industry in EM continue to be sub-optimal. As shown, two aspects of project financing are rated as the biggest challenges, which is perhaps not surprising given the prevalence of SME participants in this study. The key challenges shown below fall into all components of the continuum of continuous improvement, with a block of issues falling into the knowledge category, a capacity-building issue.

Table 10-2: Summary of Challenge Compilation Results

Category	Description of Challenge/Barrier
Financing of EE Projects	Difficult to obtain company financing to implement EE projects
	Payback period for EE projects is too long or return on investment is too low
Financing of EE Projects	Do not know where to find sources of funding and incentives
Commitment to Energy Management	Lack of human resources to focus on EM
	Production is the dominant focus, and EM is not seen as a part of production
Product and Service Availability	Do not know where to find reputable energy service providers
Knowledge of EE Opportunities	Do not know how to assess technical and economic feasibility of EE opportunities
	Do not know how to identify EE opportunities
	Limited knowledge of current EE opportunities and products
	No knowledge of benefits (cost and co-benefits) resulting from EE opportunities
	Do not know where to find information about EE opportunities and products
Transaction Costs	Too much effort to access programs providing assistance, funding and incentives
Transaction Costs	Too much effort to obtain information on funding and incentive programs
	Too much effort to obtain information on EE opportunities and products in the market
Product and Service Availability	Advanced EE products are not readily available

10.2.2 Solution Compilation Results

Workshop participants were asked to rate the importance of potential solutions for each challenge within the five categories. The top 15 solutions, in descending order of importance, are listed in Table 10-3.

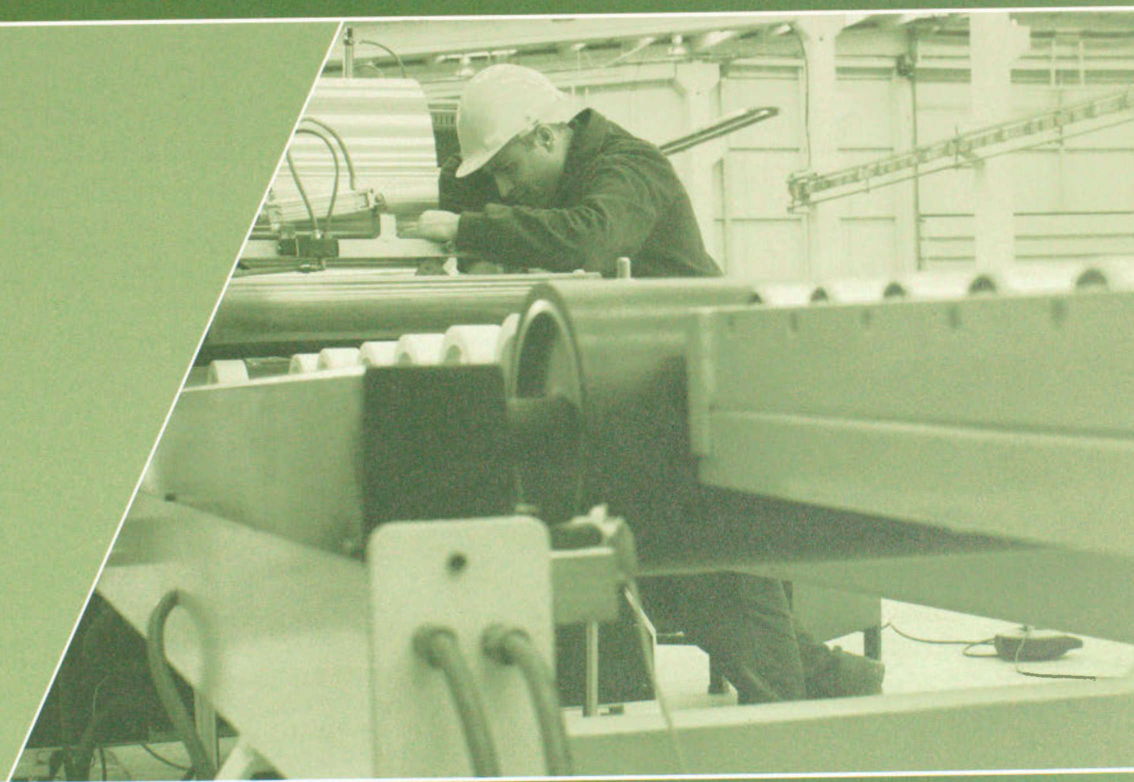
The results suggest that industry requires the following:

- An integrated, streamlined means of accessing programs aimed at improving productivity. There is inertia due, in part, to the actual and perceived transaction costs of using support programs effectively;
- The human resource capacity to manage and advance EM projects;
- Financial support for making business cases for EM measures and implementing those measures;
- Help with capacity building and adopting innovative EM and clean technology solutions.

Table 10-3: Summary of Solution Compilation Results

Category	Potential Solution
Transaction Costs	A one-stop centre/platform for accessing programs
Commitment to EM	An embedded energy manager (including an energy specialist dedicated to a group of SMEs)
Commitment to EM	Assistance in implementing the ISO standard for EM
Commitment to EM	EM capacity-building workshops
Knowledge of EE Opportunities	A centralized source of information on EE opportunities
Knowledge of EE Opportunities	Promoted and marketed knowledge centres
Financing of EE Projects	A centre that facilitates access to financing (e.g., performance contracts or third-party financing)
Knowledge of EE Opportunities	Third-party EE opportunity identification/assessments
Knowledge of EE Opportunities	Capacity-building and training workshops (technical and management)
Financing of EE Projects	Incentives to develop business cases (including detailed feasibility assessments)
Financing of EE Projects	An incentive based on amount of energy saved
Financing of EE Projects	Fixed-cost incentives for prescribed equipment
Product and Service Availability	Energy courses and plant assessment track for universities and colleges
Product and Service Availability	Commercialized EE technology and funding and centres for innovation
Product and Service Availability	Certified service providers

11 POTENTIAL REDUCTION IN GREENHOUSE GAS AND CRITERIA AIR CONTAMINANTS EMISSIONS



11 POTENTIAL REDUCTION IN GREENHOUSE GAS AND CRITERIA AIR CONTAMINANTS EMISSIONS

This section highlights the GHG and CAC emissions associated with the energy savings potential.

11.1 Methodology

The base year and reference case energy uses described in Sections 5 and 6 were converted to the equivalent GHG and CAC emissions using the emission factors summarized in Appendix B. The energy savings determined for the economic potential scenario in Section 9 were also converted.

For GHG emissions, it is important to understand the impact that electricity use has on a plant's carbon footprint. Electricity use is therefore included in the GHG emission calculations, but excluded from the CAC emission calculations.

11.2 Base Year, Reference Case and Economic Potential Scenario Emissions

The 2007 base year GHG emissions associated with energy use equal 39.5 million tonnes of CO_2e and the associated CAC emissions equal 92 900 kilograms (kg). Because of the projected increase in energy use in the reference case, it is estimated that GHG emissions will increase by 16 percent and CAC emissions by 17 percent.

If all of the economically feasible energy efficiency best practices are implemented, as per the economic potential scenario described in Section 9, the GHG emissions will be 12.6 million tonnes (t) of CO_2e (or 27 percent) less than the reference case in 2030. The economic potential scenario for CAC emission reduction is estimated to be 27 500 kg (or 25 percent). The results are shown in Tables 11-1 and 11-2.

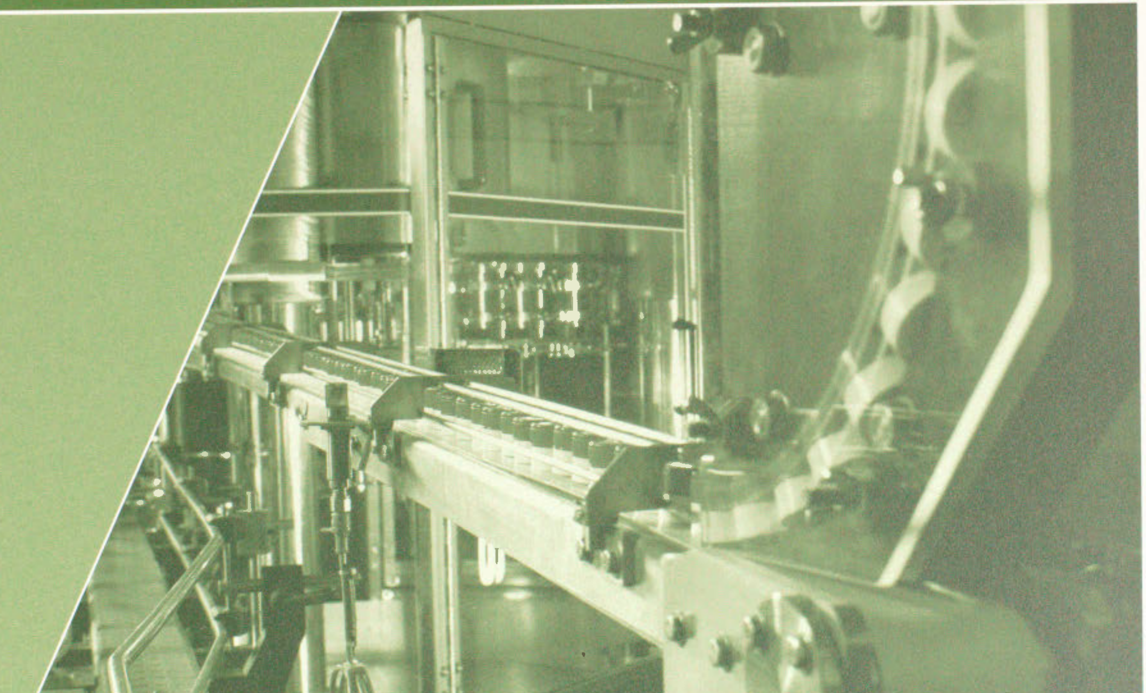
Table 11-1: 2030 Reference Case and Economic Potential Scenario for GHG Emission Savings by Subsector (1 million t of CO_2e)

	Base Year	Reference Case	Economic Potential	2030 Economic Potential Savings	
Subsector	**2007**	**2030**	**2030**	**1 million t of CO_2e**	**%**
Primary Metal	11.9	15.0	11.3	3.8	15%
Chemical	4.9	6.1	4.6	1.5	23%
Paper	3.3	3.4	2.4	1.0	24%
Non-Metallic Mineral	4.0	5.5	3.9	1.6	20%
Petroleum & Coal	2.9	4.0	2.8	1.2	21%
Transportation Equipment & Machinery	2.3	2.1	1.4	0.6	28%
Food, Beverage & Tobacco	1.9	1.7	1.2	0.5	28%
Mining	1.9	2.0	1.5	0.5	22%
Fabricated Metal	0.8	0.8	0.5	0.3	31%
Plastics & Rubber	0.8	1.0	0.7	0.3	26%
Other	4.8	4.2	2.9	1.3	27%
Total	**39.5**	**45.8**	**33.2**	**12.6**	**27%**

Table 11-2: 2030 Reference Case and Economic Potential Scenario for CAC Emission Savings by Subsector (1000 kg)

	Base Year	Reference Case	Economic Potential	2030 Economic Potential Savings	
Subsector	**2007**	**2030**	**2030**	**1000 kg**	**%**
Primary Metal	38.5	47.0	36.0	11.0	23%
Chemical	11.8	14.0	10.9	3.1	22%
Paper	5.1	5.1	3.8	1.3	26%
Non-Metallic Mineral	12.2	16.1	11.7	4.4	27%
Petroleum & Coal	6.4	9.2	6.4	2.8	30%
Transportation Equipment & Machinery	2.5	2.4	1.6	0.7	31%
Food, Beverage & Tobacco	3.0	2.8	1.9	0.9	31%
Mining	3.5	3.5	2.8	0.7	20%
Fabricated Metal	0.8	0.8	0.4	0.3	42%
Plastics & Rubber	0.7	1.0	0.7	0.3	27%
Other	8.3	7.0	5.0	2.0	29%
Total	**92.9**	**108.8**	**81.3**	**27.5**	**25%**

12 REFERENCES



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13 GLOSSARY

13 GLOSSARY

Baseline technology

The existing equipment with which upgraded technologies are compared and to which energy efficiency measures are applied.

Base year

The year with which all potentials are compared. It is used to provide a detailed description of where and how energy is currently used in each sector. For the purposes of this study, it is 2007.

Criteria air contaminants

A group of air pollutants that includes emissions of CO, SO_X, NO_X and PM. They are often products of industrial processes or of the combustion of fossil fuels.

Economic potential scenario

An estimate of the level of savings that would occur if all the TBPs that pass the economic-benefit cost test, in this case the TRC test, were applied to the industry sectors.

Economically feasible measure

An energy efficiency measure that passes the TRC test.

Energy efficiency and energy conservation best practices

The management and operation practices that represent the most advanced practices available to an industry.

Energy end-use profile

The percentage breakdown, by fuel type, of energy use for a generic plant in a given subsector.

Energy management potential analysis

An analysis designed to quantify the potential reduction in energy consumption due to EM actions. In this context, EM addresses energy consumption and not energy demand.

Generic plant

A theoretical plant used to model an average plant within a given subsector. Generic plants are composed of an energy-use profile and average energy usage.

Greenhouse gas emissions

The emissions that trap heat in the atmosphere and contribute to global warming. These gases are most often produced from the burning of fossil fuels.

Industrial and manufacturing sector

Relates to all industrial and manufacturing operations as defined by the two-digit NAICS code level and included under NAICS 21: Mining and Quarrying (excluding Oil and Gas Extraction) and NAICS 31–33: Manufacturing.

Management best practices

Practices that address the people aspect of reducing energy use. In an industrial organization, an MBP is illustrated by a high level of commitment, awareness, organization and action in support of energy efficiency. An example of an EM best practice is having a policy and plan to manage energy.

Market penetration rate

The level at which a given measure is present in the market place.

Milestone years

Key years in the study period when estimates of energy consumption and potential reductions are calculated.

Natural conservation

The future change in energy intensity that is expected to occur in the absence of government, utility or association EM programs.

Replacement measure/technology

An energy efficiency measure or technology that can be installed to replace a less efficient piece of equipment. Replacement measures are applied on an incremental cost basis because they are normally implemented once the existing piece of equipment has reached the end of its useful life and needs to be replaced anyway.

Reference case

A projection of energy use to 2030 in the absence of any new EM market interventions after 2007 (i.e., incremental to what utilities and government have already planned for this period). The reference case is the baseline against which the scenarios of energy savings are calculated.

Retrofit measure/technology

An energy efficiency measure or technology that can be used to upgrade an existing piece of equipment. Retrofit measures are applied on a full-cost basis and may be implemented immediately.

Subsector

A classification of customers within a sector based on common characteristics. Industrial subsectors are grouped by product type (pulp and paper, solid wood products, chemicals, etc.).

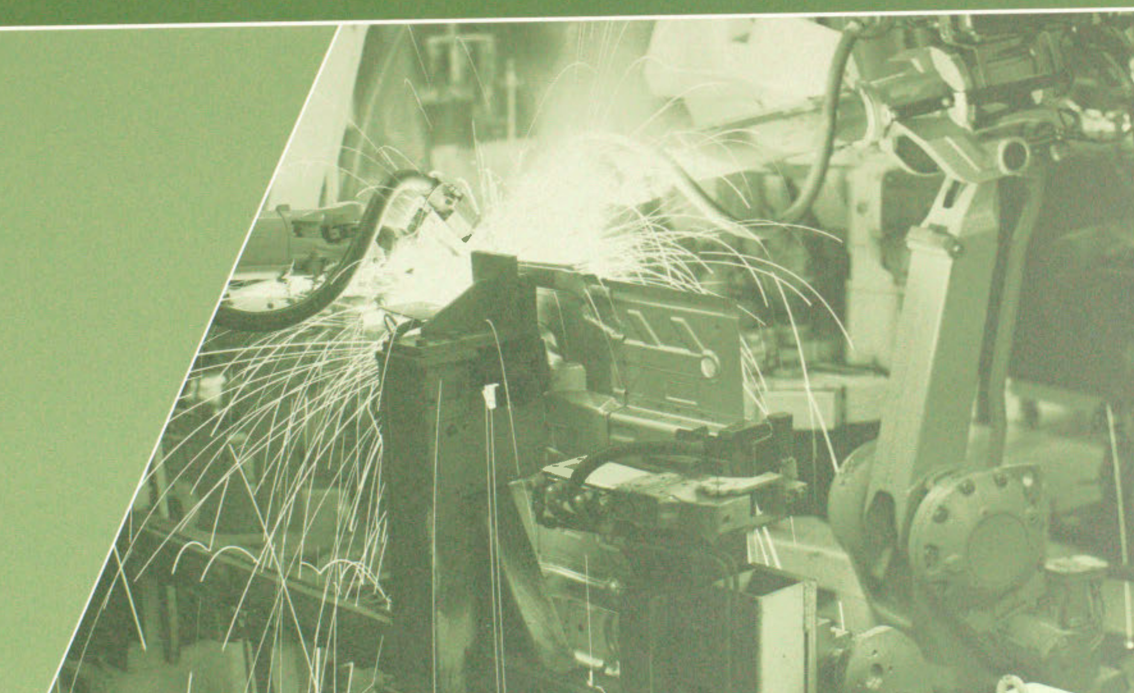
Technical best practices

A set of energy efficiency measures that represent the most advanced technology available.

Total resource cost test

An economic test that compares the total costs of energy efficiency investments with the social cost of energy production. Unpriced environmental and social costs may be accounted for by changing the cost of either the investment under consideration or the total cost of each fuel type in such a way that relative unpriced impacts are reflected.

14 ABBREVIATIONS



14 ABBREVIATIONS

CAC: criteria air contaminants

CME: Canadian Manufacturers & Exporters

CO: carbon monoxide

CO_2: carbon dioxide

CO_2e: CO_2 equivalent

EM: energy management

GHG: greenhouse gas

MBP: management best practice

NAICS: North American Industry Classification System

NEB: National Energy Board

NO_X: nitrogen oxides

NPV: net present value

PJ: petajoule

PM: particulate matter

RPP: refined petroleum products

SO_X: sulphur oxides

SME: small and medium-size enterprise

TBP: technical best practice

TRC: total resource cost

APPENDICES

APPENDIX A: TOTAL RESOURCE COST TEST AND RELEVANT PARAMETERS

The economic benefit cost test used in the study is the TRC test used to calculate the net present value (NPV) of the benefit and cost streams associated with EM measure investments according to the following equation:[11]

TRC = NPV (Annual Avoided Fuel, Electricity and Water Costs) - Capital Costs - NPV (Annual O&M Costs)

If the TRC is positive, the net benefits of the measure outweigh the costs and the measure should be implemented. This calculation includes the avoided natural gas, electricity and other fuel costs, the life of the technology and the selected discount rate.

The cash-flow stream of the TRC test benefits is based on a valuation of what are referred to as the "avoided costs," that is, the benefit to society of not having to supply the next marginal unit of energy, such as a kilowatt of electricity or a cubic metre of natural gas. Electricity supply costs include energy costs and generation, transmission and distribution capacity.

The avoided costs used in the assessment are provided in Tables A-1 and A-2.

A real discount rate of 8 percent was used in economic calculations. This rate is recommended by the Treasury Board of Canada Secretariat.[12] A sensitivity analysis of the following variables was done:

- **Discount rate:** 4 percent and 10 percent
- **GHG emission adder:**
  - Sensitivity 1: The cost of an opportunity included a carbon adder of $15 from 2012 to 2015. From 2016 to 2020, the adder was increased to $45, and from 2020 to the end of the study period, the adder was increased to $71.
  - Sensitivity 2: The cost of an opportunity included a carbon adder of $24 from 2012 to the end of the study period.
- **Capital cost of energy efficiency measure:** Decreased by 20 percent and increased by 20 percent
- **Avoided electricity and fuel cost:** Decreased by 20 percent and increased by 20 percent

[11] Ontario Energy Board. *Guidelines for Electricity Distributor Conservation and Demand Management*. 2008. Report reference number: EB-2008-0037.

[12] Treasury Board of Canada Secretariat. *Canadian Cost-Benefit Analysis Guide – Regulatory Proposals*. 2007.

Table A-1: Avoided Supply Cost

Supply	Source of Information and Assumptions	Base Year Prices (2007)
Natural Gas	Reference case natural gas price in the NEB's *Energy Futures* 2009 report	$11.66 per gigajoule (GJ)
Electricity	Avoided cost provided by the Ontario Power Authority	$15.07/GJ
RPP	Reference case heavy fuel oil price in the NEB's *Energy Futures* 2009 report	$14.79/GJ
Other	Weighted average of natural gas price and price of coal in the NEB's *Energy Futures* 2009 report	$ 3.14/GJ

Table A-2: Net Present Values of Avoided Supply Cost

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Electricity	$15.07	$13.55	$27.76	$41.11	$52.85	$64.20	$75.09	$84.99	$94.04	$102.28	$109.85	$116.77
Natural Gas	$11.66	$13.49	$22.35	$31.07	$40.51	$49.26	$57.39	$64.91	$71.85	$78.28	$84.22	$89.71
RPP	$14.79	$18.73	$29.44	$41.21	$54.06	$66.20	$77.67	$88.29	$98.12	$107.22	$115.65	$123.44
Other	$3.14	$3.81	$7.08	$10.06	$12.95	$15.64	$18.14	$20.45	$22.59	$24.57	$26.40	$28.09
Year	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Electricity	$123.06	$128.85	$134.59	$139.88	$144.77	$149.28	$153.44	$157.28	$160.83	$164.10	$167.11	$169.90
Natural Gas	$94.80	$99.51	$104.19	$108.52	$112.53	$116.24	$119.67	$122.86	$125.80	$128.53	$131.06	$133.40
RPP	$130.66	$137.36	$144.01	$150.17	$155.88	$161.17	$166.07	$170.61	$174.81	$178.71	$182.32	$185.66
Other	$29.67	$31.12	$32.57	$33.91	$35.15	$36.29	$37.36	$38.34	$39.26	$40.10	$40.89	$41.61

APPENDIX B: ENERGY CONVERSION AND EMISSION FACTORS

B.1 Energy Content Conversion Factors

The energy content conversion factors used in the analysis and associated references are summarized in Table B-1.[13]

Table B-1: Energy Content Conversion Factors

Energy Source	Unit Conversion Applies to	Conversion Factor to GJ	Units	Reference
Electricity	kWh	0.0036	GJ/kW	NEB[(a)]
Fuel Oil No. 2	m^3	38.51	GJ/m^3	NEB[(a)]
Fuel Oil No. 6	m^3	40.90	GJ/m^3	NEB[(a)]
Diesel (transport)	m^3	38.68	GJ/m^3	NEB[(a)]
Gasoline (transport)	m^3	34.66	GJ/m^3	NEB[(a)]
Propane	m^3	25.53	GJ/m^3	NEB[(a)]
Natural Gas	m^3	0.03758	GJ/m^3	Average of gas content values provided by Enbridge and Union Gas
Coal	t	25.43	GJ/t	Statistics Canada[(b)]
Steam	t	2.75	GJ/t	Statistics Canada[(b)]
Biomass – solid wood waste	t	18	GJ/t	Statistics Canada[(b)]
Biomass – spent pulping liquor	t	14	GJ/t	Statistics Canada[(b)]

(a) National Energy Board (Energy Conversion Tables: www.neb-one.gc.ca)
(b) Statistics Canada (*Energy Statistics Handbook – Fourth Quarter, 2008*)

B.2 Greenhouse Gas and Criteria Air Contaminants Emission Factors

GHG amounts are expressed in CO_2e. The emission factors used in the analysis are summarized in Table B-2. The emission factors were obtained from Environment Canada's *National Inventory Report 1990–2006: Greenhouse Gas Sources and Sinks in Canada, Annex 12: Emission Factors.* May 2008.

[13] Natural Resources Canada – Office of Energy Efficiency. *Update of Criteria Air Contaminant Emissions in GHGenius.* 2008.

Table B-2: GHG Emission Factors

GHG Emission Factor	Electricity (kWh)	Natural Gas (m^3)	RPP (m^3)	Other (t)
Emissions Coefficient (tonnes of CO_2e/unit)	0.00018	0.00189	2.70025	2.511360
Emissions Coefficient (tonnes of CO_2e/GJ fuel)	0.05000	0.00050	0.07071	0.006576

The CAC Emission factors used in the study are summarized in Table B-3.

Table B-3: CAC Emission Factors

End Use	CAC	Emission Factor (g/GJ)					
		Natural Gas	RPP	Coal	Coke	Coke Oven Gas	Biomass
Process Heating and Process Specific	CO	35.58	14.37	10.13	7.14	34.58	257.97
	NO_x	67.03	109.15	173.70	122.43	88.53	94.59
	SO_x	0.26	19.33	267.54	159.01	4.90	92.78
	PM	3.22	36.35	151.25	106.60	3.13	35.17
HVAC	CO	16.94	15.51	-	-	-	-
	NO_x	32.12	45.06	-	-	-	-
	SO_x	0.26	13.09	-	-	-	-
	PM	3.22	1.24	-	-	-	-

APPENDIX C: SUBSECTOR GENERIC PLANT PROFILES

Table C-1: Base Year Electricity Use Subsector Profile

End Use	Base Year Electricity Use (%)										
	Primary Metal	Chemical	Paper	Non-Metallic Mineral	Petroleum & Coal	Transportation Equipment & Machinery	Food, Beverage & Tobacco	Mining	Fabricated Metal	Plastics & Rubber	Other
Steam Boilers & Steam Systems	-	-	-	-	-	-	-	-	-	-	-
Hot Water Heaters & Boilers	2.0%	3.0%	2.0%	2.0%	2.0%	3.0%	1.0%	1.0%	3.0%	1.0%	3.0%
Steam Systems (imported steam)	-	-	-	-	-	-	-	-	-	-	-
Furnaces/Kilns/ Ovens/Dryers	34.0%	2.1%	2.2%	28.0%	4.6%	6.3%	2.0%	-	18.5%	8.0%	8.0%
Cooling & Refrigeration	1.6%	2.4%	1.2%	1.0%	7.8%	0.8%	28.0%	-	2.0%	3.0%	1.0%
Pumps	11.0%	16.0%	31.0%	14.0%	21.3%	15.0%	17.0%	9.4%	14.0%	13.0%	18.0%
Fans/Blowers	7.0%	12.5%	13.0%	11.0%	9.7%	12.0%	7.0%	-	10.0%	12.0%	11.0%
Other Motors	12.0%	17.0%	24.0%	7.3%	26.0%	21.0%	18.0%	28.0%	25.0%	21.0%	20.0%
Compressed Air Systems	10.0%	15.0%	19.0%	9.0%	22.5%	17.0%	14.0%	2.5%	11.0%	15.0%	18.0%
Electrochemical	3.0%	15.0%	1.0%	-	-	1.0%	-	1.0%	1.0%	-	5.0%
Process Specific	6.0%	1.0%	0.1%	26.0%	0.5%	2.5%	0.6%	17.6%	6.6%	13.0%	7.0%
HVAC	8.0%	14.0%	3.0%	0.7%	-	18.4%	8.0%	22.0%	5.5%	11.0%	5.0%
Lighting	4.4%	1.0%	1.5%	-	4.6%	2.0%	3.1%	2.5%	2.0%	2.0%	3.0%
Other	1.0%	1.0%	2.0%	1.0%	1.0%	1.0%	1.3%	16.0%	1.4%	1.0%	1.0%

Tablet C-2: Base Year Natural Gas Use Subsector Profile

End Use	Base Year Natural Gas Use (%)										
	Primary Metal	Chemical	Paper	Non-Metallic Mineral	Petroleum & Coal	Transportation Equipment & Machinery	Food, Beverage & Tobacco	Mining	Fabricated Metal	Plastics & Rubber	Other
Steam Boilers & Steam Systems	4.0%	51.0%	59.0%	14.0%	39.4%	17.0%	68.0%	1.0%	8.0%	38.0%	33.0%
Hot Water Heaters & Boilers	1.0%	5.0%	6.0%	2.0%	4.0%	3.0%	3.0%	0.0%	1.0%	4.0%	5.0%
Steam Systems (imported steam)	-	-	-	-	-	-	-	-	-	-	-
Furnaces/Kilns/ Ovens/Dryers	79.0%	26.3%	19.0%	75.0%	54.0%	29.0%	23.0%	22.0%	78.0%	20.0%	40.0%
Cooling & Refrigeration	-	-	-	-	-	-	-	-	-	-	-
Pumps	-	-	-	-	-	-	-	-	-	-	-
Fans/Blowers	-	-	-	-	-	-	-	-	-	-	-
Other Motors	-	-	-	-	-	-	-	-	-	-	-
Compressed Air Systems	-	-	-	-	-	-	-	-	-	-	-
Electrochemical	-	-	-	-	-	-	-	-	-	-	-
Process Specific	11.0%	-	1.9%	0.0%	0.3%	7.0%	0.0%	0.0%	0.0%	0.0%	0.0%
HVAC	4.0%	16.7%	13.1%	7.0%	1.3%	38.0%	4.0%	65.0%	11.0%	34.0%	21.0%
Lighting	-	-	-	-	-	-	-	-	-	-	-
Other	1.0%	1.0%	1.0%	2.0%	1.0%	6.0%	2.0%	12.0%	2.0%	4.0%	1.0%

Table C-3: Base Year RPP Use Subsector Profile

End Use	Base Year RPP Use (%)										
	Primary Metal	Chemical	Paper	Non-Metallic Mineral	Petroleum & Coal	Transportation Equipment & Machinery	Food, Beverage & Tobacco	Mining	Fabricated Metal	Plastics & Rubber	Other
Steam Boilers & Steam Systems	1.0%	60.0%	55.0%	4.0%	16.6%	40.0%	86.0%	0.0%	1.0%	40.0%	60.0%
Hot Water Heaters & Boilers	-	-	-	-	-	-	-	-	-	-	-
Steam Systems (imported steam)	-	-	-	-	-	-	-	-	-	-	-
Furnaces/Kilns/ Ovens/Dryers	84.0%	20.0%	5.0%	71.0%	71.0%	5.0%	5.0%	-	74.0%	5.0%	20.0%
Cooling & Refrigeration	-	-	-	-	-	-	-	-	-	-	-
Pumps	-	-	-	-	-	-	-	-	-	-	-
Fans/Blowers	-	-	-	-	-	-	-	-	-	-	-
Other Motors	-	-	-	-	-	-	-	-	-	-	-
Compressed Air Systems	-	-	-	-	-	-	-	-	-	-	-
Electrochemical	-	-	-	-	-	-	-	-	-	-	-
Process Specific	-	-	-	-	0.4%	-	-	46.7%	-	-	-
HVAC	-	-	-	-	-	-	-	-	-	-	-
Lighting	-	-	-	-	-	-	-	-	-	-	-
Other	15.0%	20.0%	40.0%	25.0%	12.0%	55.0%	9.0%	53.3%	25.0%	55.0%	20.0%

Table C-4: Base Year Other Fuel Use Subsector Profile

End Use	Base Year Other Fuel Use (%)										
	Primary Metal	Chemical	Paper	Non-Metallic Mineral	Petroleum & Coal	Transportation Equipment & Machinery	Food, Beverage & Tobacco	Mining	Fabricated Metal	Plastics & Rubber	Other
Steam Boilers & Steam Systems	5.0%	-	3.0%	-	-	-	-	1.0%	-	-	8.0%
Hot Water Heaters & Boilers	-	-	-	-	-	-	-	-	-	-	-
Steam Systems (imported steam)	-	29.0%	97.0%	-	-	-	-	-	-	-	-
Furnaces/Kilns/ Ovens/Dryers	90.0%	66.0%	-	100.0%	-	-	-	5.0%	-	-	40.0%
Cooling & Refrigeration	-	-	-	-	-	-	-	-	-	-	-
Pumps	-	-	-	-	-	-	-	-	-	-	-
Fans/Blowers	-	-	-	-	-	-	-	-	-	-	-
Other Motors	-	-	-	-	-	-	-	-	-	-	-
Compressed Air Systems	-	-	-	-	-	-	-	-	-	-	-
Electrochemical	-	-	-	-	-	-	-	-	-	-	-
Process Specific	5.0%	5.0%	-	-	-	-	-	-	-	-	-
HVAC	-	-	-	-	-	-	-	-	-	-	-
Lighting	-	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	100.0%	100.0%	100.0%	94.0%	100.0%	100.0%	52.0%

APPENDIX D: BEST PRACTICES

D.1 Management Best Practices

Table D-1 Management Best Practices

Corporate Energy Management Policy and Planning	The company has a documented corporate energy management policy that • defines long-term strategic energy management commitments and goals; and • specifies responsibilities and sets targets for controlling energy use and cost.
	The company has a documented energy management planning process that annually • sets targets for controlling energy use and cost; • sets out actions to be taken to reduce energy costs and achieve energy performance targets; • integrates the energy use and cost-reduction targets and actions with annual corporate production and cost objectives; and • defines a policy and guidelines on energy performance measurement and verification.
Corporate Financing of Energy Management	The company treats EM as a key financial variable in every capital project and its contribution is clearly determined.
	The company has formal procedures that make it possible for capital and operating financial allocations for EM projects to • have the same level of authority and importance as other corporate capital and operating financial allocations; and • be assessed using similar methods and processes as other plant capital and operating financial allocations.
	The company requires that the business case development for all EM projects include an assessment of energy cost avoidance, maintenance cost reduction, productivity improvements and reduced environmental compliance costs.
	The company requires that EM investments be assessed using a life cycle cost analysis methodology that converts estimated savings and cost data into a cash flow and integrates that cash flow with other decision-making metrics.
Corporate Organization and Accountability	The company has a designated senior manager who is accountable for implementing the corporate EM policy and meeting the energy use performance targets.
	The company also makes several senior managers accountable for implementing the corporate EM policy and meeting the company's energy use performance targets.
	The company regularly conducts corporate and facility energy assessments and applies benchmarking using key performance indicators.
	The company's EM policy and/or internal technical standards specify EM measurement and verification requirements.
	Internal auditing of the corporate EM policy, planning and activities is conducted as a formal part of existing audit systems and protocols.
	External auditing is deployed to check the company's EM system and database accuracy and verify measurement system accuracy.

Corporate Communications	The corporate EM policy or strategy is communicated ***externally*** (e.g., posted on the company Web site).
	The corporate EM policy or strategy is communicated ***internally*** (e.g., posted on bulletin boards in the plant[s]).
	Energy use key performance indicators are communicated ***externally*** (e.g., posted on the company Web site).
	Energy use key performance indicators are communicated ***internally*** (e.g., posted on bulletin boards in plant[s]).
	Energy costs and cost management are communicated in the company's annual report along with a management discussion of energy's impact on the business.
	Energy costs and cost management are communicated to the plant(s) on a quarterly basis (or more frequently).
Facility-Level Energy Management – Organization and Accountability	The facility has a formal organizational, reporting and responsibility structure (with an organization chart) identifying EM accountabilities at all management, supervisory and operator levels.
	The facility has a designated senior energy manager who is responsible for implementing the EM component of the facility's annual business plan.
	The designated senior energy manager defines energy performance goals in the annual employee performance appraisals.
	The facility also has a senior facility management team (e.g., senior production process and technical managers) that is accountable for energy costs and energy use performance metrics.
	The senior facility management team defines energy performance goals in the employee performance appraisals.
	The facility has an energy committee led by the senior energy manager and other personnel (e.g., technical and operations personnel).
	Facility employees are aware of energy performance targets and the commitment to actions that improve energy use performance as stated in the facility's annual operational business plan.
	The facility has systems and resources in place to adequately meet the energy performance reporting requirements in the business plan.

Facility-Level Energy Management – Monitoring	The facility maintains an active energy procurement plan that reviews energy bills and energy consumption data and assesses the tariff structure.
	The facility operates an EM information system that comprises the following: • sensors and instruments to collect energy use data, including energy meters (electricity, gas, oil, steam) and other utility meters directly associated with energy use (heat flow, cooling flow, compressed air flow), temperature, pressure and flow; • data acquisition systems (e.g., energy meters are usually connected to a monitoring and control system, such as a programmable logic controller, supervisory control and data acquisition, or distributed control system); • an energy-use database in which data collection is usually automated and uses a data historian that is designed for time-series data storage; and • software tools that typically integrate directly with the control/monitoring system and data historian to analyse energy use against key energy use performance indicators.
	Energy consumption is measured on a basis that can be • easily related to an operational unit; • measured per physical unit of product; • identified for each operational area in both real time and periodically; • correlated to production; and • correlated to weather.
	The difference between actual and targeted energy consumption is tracked at the facility and production process levels, and causes of increased or decreased consumption are assessed.
	All energy metrics (e.g., real-time energy data, synchronized real-time production data and reports) can be accessed from a desktop computer by approved personnel.
Facility-Level Energy Management – Reporting and Communication	The facility uses a consistent communications and reporting protocol to channel key performance indicator results and relevant energy use information to business units and staff.
	The facility regularly reports energy use performance relative to targets and budgets (e.g., annual, quarterly and monthly) to people with accountability at the corporate and facility levels (e.g., operations and technical managers).
	Key energy use performance indicator results (e.g., real-time energy costs) are communicated to all employees on a regular basis.
	The facility uses a variety of tools as part of an ongoing energy awareness campaign to display performance, ideas, etc.
	Energy saving and other EM ideas are solicited from employees during safety or general employee meetings.
	EM project costs and progress are reported to the facility's technical and operations management.
	EM project costs and progress are reported to corporate management.

Facility-Level Energy Management – Project Management	**Identification of Opportunities** The plant typically considers the scope of EM project opportunities to include the following: • Energy efficiency and conservation • Peak load and demand management • Utility bill management • Fuel substitution and/or use of renewable energy sources • On-site power generation • Improved EM information systems
	The facility uses the following means to identify EM project opportunities: • A suggestion plan administered by the energy manager or other senior staff • Energy audits and studies • Internal and external benchmarking and detailed analyses of production processes and infrastructure consumption patterns • Routine maintenance activities • The facility's continuous improvement management system • Existing metering, additional submetering if required and EM information systems
	EM best practices are identified by regularly monitoring trade journals and internal databases and by networking with other facilities. Best practices are shared throughout the facility and developed into projects.
	Project Implementation • The facility has a procedure for managing the implementation of EM projects. • The facility has designated a project manager to oversee the implementation of EM projects.
	Project Measurement and Verification • Project measurement and verification plans are normally carried out as part of the design for all energy performance improvement projects requiring capital allocations. • The costs of implementing a project measurement and verification plan are normally included in the cost analysis of the project. • The measurement and verification plan requires the establishment of energy performance baselines and a formal reporting process of actual vs. baseline performance.

Facility-Level Energy Management – Training and Capacity Development	Staff training to support EM is included in the annual facility budget.
	The approved staff training plan for EM is incorporated into the annual employee training schedule.
	The staff training plan for EM includes both management and technical training competencies.
	Energy use and EM is included in orientation training for new personnel.
	Senior facility staff accountable for energy use and cost performance targets are trained to • conduct EM planning as a key part of the business planning processes; • prepare and submit a financial business case evaluation of energy performance improvement projects in terms relevant to the financial criteria of the corporate project approval process; and • scope out, budget and manage pre-feasibility and investment grade studies.
	Designated facility personnel are trained to oversee and manage the identification and implementation of EM projects.
	Designated facility personnel are trained to manage energy data and information.

D-2 Technical Best Practices System

Submetering

Submetering systems measure the amount of energy a plant uses, particularly certain portions of the plant where major utility loads are known. Submetering can be beneficial as part of a control system or an EM plan. Well-placed submeters provide utility usage information for specific processes or plant areas that can help the plant identify potential areas of improvement within. Data obtained from meters are only beneficial for demand-side management (DSM) if interpreted and used in a DSM system or energy management framework, including monitoring and targeting strategies. Also, the closer the meter is to the end user, the more likely that he or she will be held accountable, which can lead to further savings.

Energy Management

EM addresses the people aspect in reducing energy use and can include policies and plans to manage energy. Simply applying technical measures is not enough to fully take advantage of energy savings opportunities. An EM plan helps to structure future activities and set energy targets.

Integrated Control System

Traditionally, control systems have been implemented as separate entities, each with its own infrastructure, installer and service. This can result in control systems that, as a whole, are not utilized to their maximum potential. Applications of advanced automated control and EM systems in varying development stages can be found in all industrial sectors; however, there is still considerable potential for implementing control and management systems because more modern systems enter the market continually.

Process control systems depend on information at many stages of the processes. The sensor information is used in control systems to adapt the process conditions, based on mathematical (rule-based) or neural networks and "fuzzy logic" models of the industrial process. Neural network-based control systems have been used successfully in the cement (kilns), food (baking), non-ferrous metals (alumina, zinc), pulp and paper (paper stock, lime kiln), petroleum refineries (process, site) and steel industries (EAFs, rolling mills). New energy management systems that use artificial intelligence, fuzzy logic (neural network) or rule-based systems mimic the "best" controller using monitoring data and learned information from previous experiences.

D-3 Boiler, Hot Water and Steam Systems

Condensing Boiler

High-efficiency condensing boilers feature advanced heat exchanger designs and materials that extract more heat from the flue gases before they are exhausted. The temperature of the flue gases is reduced to the point where the water vapour produced during combustion condenses back into liquid form and releases the latent heat, which improves energy efficiency.

Modern condensing boilers have energy efficiencies of 90 to 96 percent, while new conventional non-condensing models have energy efficiencies up to 85 percent. Many boilers over 20 years old typically operate at overall water-to-steam boiler efficiencies of less than 70 percent, making them good candidates for upgrading or replacement. A number of natural gas-fired condensing boilers are available, but very few oil-burning models are on the market. New boilers are generally installed only at the end of the life of existing boilers or when expansion occurs.

Instantaneous Steam Generation

When a boiler is too big, boiler short-cycling losses may occur, because an oversized boiler will turn on and off more often than a boiler that has been properly matched to demand. Every time the boiler turns on, extra energy is required to heat it back up to steady state. Conversely, a boiler left on standby will avoid the extra energy used to heat back up to steady state, but will waste energy while in standby. Instantaneous steam generators do not need to be left on standby and do not require a large amount of energy to reach steady state performance. The relatively small water content of a coil-type steam generator, for example, enables it to go from cold start-up to full steam output in approximately five minutes. Instantaneous steam generation systems can also be beneficial when full modulation, high-output turndown ratios or rapid start-ups are required. There is a large market potential for instantaneous steam generators.

High-Efficiency Burners

Because of varying temperature requirements and the wide range of boiler models, a variety of burners is available, and burner technology is continuously improving. Improvement in boiler-burner efficiency is mainly associated with optimum combustion efficiency and improving the heat profile inside the combustion chamber. The efficiency of boiler burners is closely linked with the boiler controls regulating the fuel-to-air ratio. For example, inefficient fuel-to-air ratio control will reduce the efficiency of the burner.

Economizer

An economizer is a heat exchanger designed to use heat from hot boiler flue gases to preheat water. Economizers are often used to preheat the feedwater for large utility steam boilers using recovered stack heat. The same principle can be applied to smaller heating boilers when there is a nearby demand for hot water. With rising energy prices, these installations have become more economical; smaller, lighter and more durable economizers have been developed. A condensing economizer reclaims flue gas heat more effectively by cooling the flue gas below the dewpoint. The condensing economizer thus recovers both the sensible heat from the flue gas and the latent heat from the moisture that condenses. The condensate is highly corrosive and requires measures to ensure that it does not enter the boiler. New boilers generally include economizers, while a large percentage of existing boilers have the potential to be retrofitted with an economizer.

Boiler Rightsizing and Load Management

An oversized boiler will turn on and off more often than a boiler that has been properly matched to the demand, which may result in boiler short-cycling losses. If the boiler is left on standby, short-cycling losses will be avoided, but energy will be wasted. Rather than sizing a boiler to meet the highest possible load, fuel savings can be achieved by adding a smaller boiler, sized to meet the plant's average loads, or by re-engineering the power plant so that it consists of multiple small boilers. Multiple small boilers offer reliability and flexibility; operators can follow load swings without over-firing and short cycling. Load management also helps reduce load variation. Because this measure is normally an end-of-life option, there should be no incremental costs involved in rightsizing a boiler, but there is a benefit to be obtained from purchasing a smaller boiler. Market penetration of the measure is relatively small and depends on the replacement rate of existing boilers and installation of new boilers.

Blowdown Heat Recovery

The boiler blowdown process involves periodically or continuously removing water from a boiler to remove accumulated dissolved solids and/or sludge. During the process, water is discharged from the boiler to avoid the negative impacts that dissolved solids or impurities have on boiler efficiency and maintenance. However, boiler blowdown wastes energy because the blown down liquid is at about the same temperature as the steam produced. Much of this heat can be recovered by routing the blown down liquid through a heat exchanger that preheats the boiler's makeup water. The recovered heat can be used to preheat boiler makeup water before it enters the deaerator and to heat water inside the deaerator (for low-pressure steam), which reduces the cost of running the deaerator and improves overall boiler efficiency. Blowdown heat recovery is more prevalent in larger boilers in large facilities, but it is believed that the market penetration of the measure is still relatively small, based on consultant experience.

Boiler Combustion Air Preheat

Combustion air preheaters are similar to economizers in that they transfer energy from the flue gases back into the system. In these devices, however, the energy is transferred to the incoming combustion air. The efficiency benefit is roughly 1 percent for every 40°F increase in the combustion air temperature. Changes in combustion air temperature directly affect the amount of combustion air supplied to the boiler and may increase or decrease the excess air (see below under Advanced Boiler Controls for a discussion on air-fuel ration control.) Preheating boiler combustion air has a relatively low market penetration rate where existing boilers are concerned.

Process Heat Recovery to Preheat Makeup Water

Recovered process heat can be a good source of energy to preheat boiler makeup water. Waste heat can be captured from a clean waste stream that normally goes into the atmosphere or down the drain and can then be used to heat the makeup water before it is sent to the boiler. Many potential opportunities cannot be implemented because of factors such as distance between the process and the boiler, available heat in the process stream, volume of the process stream and consistency of the heat generation. The measure is not widely implemented, especially in small and medium-size facilities. Consequently, a significant potential remains.

Condensate Return

The primary purpose of an effective condensate recovery system is to make the utmost effective use of all remaining steam and condensate energy after process use. Condensate (water or condensed steam) reduces the quality of the steam, but is too high in value to simply discard. Maximizing the amount of condensate that is returned to the boiler can save both energy and water treatment chemicals. The value of the condensate varies with its pressure and temperature, which depends on the operating pressure of the steam system. If boiler feedwater is 60°F and the condensate is 212°F, then each pound of condensate contains at least 162 British thermal units (BTUs). If the boiler is operating at 80-percent efficiency, it represents 190 BTUs. Condensate under pressure and above 212°F can be flashed to steam for additional energy value/recovery.

The feasibility of returning condensate to the boiler depends on the distance to the boiler and the volume of the condensate. Longer distances and smaller volumes negatively affect the feasibility of returning the condensate. Condensate return has achieved a relatively significant market penetration, but a substantial number of boiler steam systems still do not include condensate return systems.

Advanced Boiler Controls

Modern burners are increasingly using servomotors with parallel positioning to independently control the quantities of fuel and air delivered to the burner head, an alternative to complex linkage designs. Controls without linkages allow for easy tune-ups and minor adjustments and provide accurate point-to-point control while eliminating hysteresis, or lack of retraceability. These controls provide consistent performance and repeatability as the burner adjusts to different firing rates. Variable frequency drives can also be used to control the air supply more accurately.

Other technologies included in combustion controls are metered control, cross-limited control, oxygen trim controls and carbon monoxide trim controls. Advanced boiler controls are generally one of the first energy efficiency measures that a facility will implement to improve boiler energy efficiency. Although the measure has achieved a substantial market share, a large market still remains.

Blowdown Control

Boiler water must be blown down periodically to prevent scale from forming on boiler tubes. This process can be wasteful if too much is lost to blowdown. Automatic blowdown controls measure and respond to boiler water conductivity and acidity to ensure that only the right amount of blowdown water is used. Although automatic blowdown control is becoming a standard practice for new boilers, a large percentage of existing boilers do not have automated control.

Insulation

Insulation increases the amount of energy available for end uses by decreasing the amount of heat lost from the distribution system. Insulation removed during maintenance is often not replaced, and older insulation deteriorates with time. To improve the energy efficiency of the system, regular insulation surveys help identify areas with insufficient insulation. A significant number of facilities do not have regular insulation surveys.

Boiler Maintenance

An upgraded boiler maintenance program, including optimization of the air-to-fuel ratio, burner maintenance and tube cleaning, can save about 2 percent of a facility's total energy use and has an average simple payback of five months. Periodic measurement of flue gas oxygen, CO, opacity and temperature provides the fundamental data required for a boiler tune-up.

A typical tune-up might include reducing excess air (and thereby excess oxygen), cleaning the boiler tube and recalibrating the boiler controls. A comprehensive tune-up with precision testing equipment to detect and correct excess air losses, smoking, unburned fuel losses, sooting and high stack temperatures can result in boiler fuel savings as high as 20 percent; typical savings are about 8 percent of boiler fuel usage.

Boiler maintenance programs are a relatively common practice, especially for large boilers and in large industries.

Boiler Water Treatment

Proper conditioning of boiler water can increase the efficiency of the boiler as well as extend its life. Some of the technologies that are employed to remove undesirable impurities from the water supply include reverse osmosis, electrodialysis and electrodialysis with current reversal. These are all known as membrane processes. Reverse osmosis uses semi-permeable membranes that let water through but block the passage of salts. In electrodialysis, the salts dissolved in the water are forced to move through cat-ion-selective and anion-selective membranes, which remove the ion concentration. Proper boiler water treatment is a relatively common practice, especially for larger boilers.

Minimized Deaerator Vent Losses

A deaerator removes dissolved oxygen from boiler feedwater and must vent this oxygen, and any other non-condensable gases that were removed, into the atmosphere. A very small percentage of steam will also vent when the gases are vented. The amount of steam vented should be minimized through proper operation and controls.

If the deaerator is operated at very high pressures, excessive venting of steam into the atmosphere may occur. The deaerator tank should not be operated based on pressure and temperature, but rather to meet water chemistry requirements for oxygen and CO_2. This measure has been implemented on a relatively limited scale.

Steam Trap Survey and Repair

Steam traps are important to the performance of both end-use equipment and the distribution system. Traps allow for condensate removal with little or no steam loss. If the traps do not function properly, excess steam will flow through the end-use device or the condensate will back up into it. Excess steam loss will lead to costly operations, and condensate backup will promote poor performance and may lead to water hammer. Traps can also remove non-condensable gases that reduce heat-exchanger effectiveness. Regular steam trap surveys are an important measure to identify faulty steam traps and steam leaks. Repairing the steam leaks and faulty steam traps will minimize steam losses and improve system efficiency.

Steam trap surveys and repair are generally one of the first energy efficiency measures implemented by plants and are implemented by a large segment of the industrial sector.

Direct Contact Hot Water Heaters

In direct contact hot water heaters, the combustion gas is in direct contact with the water and there is no heat transfer medium between the gas and the water (e.g., incoming water flows downward through a vertical column filled with stainless steel packing rings). As cold water comes into direct contact with rising hot combustion air from a gas burner, a very rapid heat transfer occurs, and the heat energy is absorbed into the water. Compared to heat exchanger-type water heaters, direct contact heaters are more efficient because they eliminate the performance reductions caused by heat losses via the heat transfer medium and by fouling of the heat exchange surfaces and the associated energy losses. However, efficiency can be greatly reduced by high return fluid temperatures.[14] Direct-contact hot water heaters are most often installed when an existing water heater needs to be replaced because of its age and associated higher maintenance requirements. The market penetration of the technology is relatively small, and there is significant potential to increase the market penetration.

D-4 Process Direct Heat (Furnaces, Kilns, Ovens, Dryers)

High-Efficiency Ovens

Infrared (IR) ovens use less energy than convection ovens because they heat the parts directly. Unlike convection ovens, they do not heat the air. IR ovens may also be used as booster ovens when final curing requires convection heating. IR ovens can either replace or be an addition to existing convection ovens, and production rates may increase significantly when an IR oven replaces a convection oven.

[14] CADDET Energy Efficiency. *Ultra-high Efficiency Direct Contact Water Heater*. www.caddet.org.

Natural gas savings and production speed increases of up to 50 percent were reported when an IR oven was used as a booster oven. A simple payback period of 2.5 years was reported for the installation of an IR oven as a booster oven.[15] In cases where IR ovens replaced convection ovens, reported simple payback periods ranged between 10 months and 3.5 years.[16]

Airflow in convection ovens is important to ensure uniform distribution of heated air, which improves product quality and optimizes the volume of heated air required. In medium- to low-temperature applications, some energy-efficient units incorporate internal recycling of airflow to optimize airflow distribution. Air-heat seals at the entrance and exit of units limit heat loss with airflow.

Recovered heat from flue gas can be used to preheat oven burners or heat other media such as makeup air or product. (See also Boiler, Hot Water and Steam Systems.)

Specific to Transportation and Machinery

Research relevant to paint ovens includes developing paints or coatings that cure faster or require less energy to cure, such as powder slurry coats. The base coat does not need to be heated to high temperatures in order to apply powder slurry coats; energy is therefore saved in the drying process. A wet-on-wet painting process eliminates the baking process between the two coats of paint. Honda and Toyota have used this process at their facilities since 1998.

Specific to Food and Beverage Subsector

A wide range of oven sizes and designs are used in the food and beverage subsector. Advances in oven energy efficiency are primarily related to improved control systems, improved combustion efficiency, reduced energy losses and reclaimed heat from exhaust gas (see also Flue Gas Heat Recovery and High-Efficiency Burners). Actual energy use and efficiencies also vary widely, depending on oven type and application.[17]

Reducing the speed of the recirculation fan and reducing the exhaust rate can minimize the energy loss when the oven is in standby mode. For example, in standby mode, the temperature of the oven is maintained when the door is open.

The reported average payback period for eight heat recovery projects at various international locations is four years.[18] The inclusion of improved burners, control systems and insulation would further decrease the payback period.

As an end-of-life measure, the implementation of high-efficiency ovens is dependent on the turnover rate of existing ovens and the need for new ovens.

High-Efficiency Dryers

A large variety of dryers, ranging in size and design, are used in the food, chemical, paper and miscellaneous sectors. Besides the design of dryers, advances in energy efficiency include improved

[15] U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy, Industrial Technology Program. *Infrared oven saves energy, lifts production at a metal finishing plant*. 2004.

[16] Ernest, Orlando. Lawrence Berkley National Laboratory. *Energy Efficiency Improvement and Cost Saving Opportunities for the Vehicle Assembly Industry*. 2003. Report reference number: LBNL 50939.

[17] U.S. Gas Research Institute – Energy Utilization Centre: Research Collaboration Program. *Food Processing Technology Project – Phase 1*. 2003.

[18] Ernest, Orlando. Lawrence Berkley National Laboratory and the American Council for an Energy Efficient Economy (ACEEE). *Emerging Energy-Efficient Industrial Technologies*. 2000. Report reference number: LBNL 46990.

control systems, improved combustion efficiency, reduced energy losses and reclaimed heat from exhaust gas.

Advanced drying technology usually aims to improve the heat transfer between the combustion gas and the product (e.g., the pulsed fluidized bed dryer, helix dryer and the pulse combustion flash dryer). The pulsed fluidized bed dryer uses a periodic hot air supply and has a wide range of applications. The helix dryer is a cylindrical chamber with a centrally located hollow column through which hot gas is supplied to the helical trays. The pulse combustion flash dryer uses intermittent combustion of fuel, which generates intense pressure, velocity and temperature waves. The helix dryer must still be proven on a commercial scale, while the other two technologies are available for commercial applications. Energy use and efficiencies also vary widely, depending on dryer type and application.[19]

Replacing a steam system with a direct-fired system, e.g., implementing a direct-fired gas system to dry barley in a malting plant, can save a significant amount of natural gas. Pre-drying stages or multiple drying stages can increase the production rate and reduce the natural gas consumption per production unit.

High-Efficiency Kilns

Roller kilns, which use rapid-firing technology, are more efficient than conventional tunnel kilns in the clay and ceramic industries. In the rapid-firing process, the clay is prepared dry and the reduced water content results in reduced heating times. Roller kilns are used successfully in Europe and the United States. Current kilns may have single- or double-layer designs and are well-suited for ceramic products, but may be less suitable for larger-capacity brick kilns. Energy performance can be improved by recovering heat from the flue gases and retrofitting or installing improved insulation with low thermal mass (LTM) materials. A simple payback period of 3.2 years is reported for the installation of a roller kiln in the place of a tunnel kiln, and relatively high fuel savings are reported when tunnel kilns are replaced with roller kilns and improved LTM insulation.[20]

Suppliers of roller kilns are developing multi-layer kilns, which will increase production rates and reduce the rate of energy usage per production unit. Additional fuel savings will be associated with improved heat recovery, burner design and control systems (see also "Gas Exhaust Heat Recovery," "High-Efficiency Burners" and "Advanced Heating and Process Control").

High-Efficiency Furnaces

The main advances in furnaces are related to combustion control, waste-heat recovery and better design. Preheating combustion air using high-velocity burners, pulse firing, recuperators or regenerative burners can improve the heat transfer of the combustion system. Specific improvements are usually applicable to specific furnaces (see also the High-Efficiency Burners profile).

Advanced furnace design includes a highly preheated combustion air system with/without oxygen enrichment.[21] Porous wall radiation barrier (PWRB) heating mantles reportedly result in a heat

[19] U.S. Gas Research Institute – Energy Utilization Centre: Research Collaboration Program. *Food Processing Technology Project – Phase 1*. 2003.

[20] Ernest, Orlando. Lawrence Berkley National Laboratory and the American Council for an Energy Efficient Economy (ACEEE). *Emerging Energy-Efficient Industrial Technologies*. 2000. Report reference number: LBNL 46990.

[21] U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program. *Development of a highly preheated combustion air system with/without oxygen enrichment*. 2004.

transfer rate in the 1800°F to 2400°F range that is two to four times greater than conventional gas-fired mantles.[22] An improvement in insulation material will reduce heat losses from the furnace shell. Research to develop new composite materials for insulation has been undertaken at the Lawrence Berkley National Laboratory and is expected to contribute to the overall efficiency of furnaces.[23]

Specific to Primary Metal and Transportation and Machinery Sectors

Recycled aluminum production uses 90 percent less energy than primary aluminum production. Several new technologies have emerged that help to improve the recovery or processing of scrap or reduce energy use when preparing and melting scrap. Examples of these new technologies include a decoating kiln (the IDEX™), which reported a relatively high reduction in kiln energy use, and a new melt design that preheats and decoats the scrap in a dry hearth furnace and then melts the scrap in a closed-well furnace.

Specific to Non-metallic Mineral Sector

State-of-the-art furnace technology in glass production uses a higher percentage of recycled glass, also called cullet. Glass manufactured in North America contains 20 percent cullet on average, while European container glass manufacturers sometimes use 80 percent cullet. Increasing cullet use by 10 percent reduces fuel use by approximately 2.5 percent.

Increasing the cullet percentage in glass containers requires more efficient waste glass collection. The reported simple payback period for furnaces with 100 percent cullet percentage and cullet preheating is two years. Energy efficiency can be further improved by batch cullet preheating and by recovering the flue gas heat. Cullet preheaters have been under development since 1980 and commercial applications can be found in Europe; development projects are ongoing in the United States.

Induction Heating

This heating technology utilizes an alternating magnetic field to induce electric eddy currents in the material being heated. The eddy currents dissipate energy, which heats the material. A coil that surrounds the material and is charged with an alternating current produces the alternating magnetic field. Induction heating competes with other heating technologies, such as fossil fuel and resistance heating.

High-Efficiency Burners

Because of differing temperature requirements and applications, a wide variety of burners is available. Burner technology is also continuously improving. Efficient burner technology generally recovers heat from the flue gas and includes recuperative- and regenerative-style burners. These burners are more efficient at higher-temperature applications. Advances over the past five years include the commercialization of self-recuperative and self-regenerative burners that use staged combustion to achieve flameless combustion. This results in more uniform heating, lower peak flame temperatures, improved efficiency and lower NO_X emissions.

[22] U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy. Combustion Fact Sheet: Innovative energy-efficient high-temperature gas-fired furnace. 2001.

[23] U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy. Industrial Material for the Future Project Fact Sheet: Advanced nanoporous composite materials for industrial heating applications. 2002.

There are numerous other types of high-temperature burner technologies that improve on previous technologies. Examples include rotary burners, dilute oxygen combustion systems, oscillating combustion, and low-NO_x burners with a vacuum-swing-adsorption oxygen system, referred to as air-oxygen/fuel burners. More specifically,

- Rotary burners control gas pressure to ensure the desired fuel-to-air ratio;
- Dilute oxygen combustion relies on the rapid and complete mixing of fuel and oxygen jets with hot furnace gases containing low levels of oxygen;
- Oscillating combustion systems use a valve to oscillate the fuel flow rate to the burner. Oscillation creates successive fuel-rich and fuel-lean zones within the flame. Heat transfer to the load is increased because of more luminous fuel-rich zones and the breakup of the thermal boundary layer, which shortens heat-up times.

Air-oxygen/fuel burners use an innovative air-oxy natural gas burner that achieves high productivity and energy efficiency with low NO_X emissions.

Modern burners are increasingly using servomotors with parallel positioning to independently control the quantities of fuel and air delivered to the burner head. These controls provide consistent performance and repeatability as the burner adjusts to different firing rates. Alternatives to electronic controls are burners with a single drive or jackshaft.[24]

Examples of advanced burner technologies include radiation stabilized burners (RSBs), forced internal recirculation (FIR) burners and low-swirl burners (LSBs). More specifically,

- The RSB is a fully premixed, semi-radiant, surface-stabilized burner developed to provide high thermal efficiency and produce very low emissions of NO_X and CO in industrial boilers and process heaters;
- The FIR burner aims to reduce emissions while maintaining boiler efficiency. The FIR burner operates with premixed sub-stoichiometric combustion and significant internal recirculation of partial combustion products. Both the RSB and FIR burners are available commercially;
- The LSB is being developed to achieve ultra-low NO_X emissions and increase system efficiency. The burner system combines a low-swirl flame stabilization method with internal flue gas recirculation. It is also being optimized to utilize partially reformed natural gas.

In addition to the high-efficiency burners discussed above, the use of oxy-gas is one of the major efficiency improvements of high-temperature applications such as furnaces and kilns. Replacing air with oxygen eliminates the need to heat and process large volumes of nitrogen present in the air. This reduces energy use and enables a reduction in equipment size. In many industrial activities, air quality regulations drive the demand for high efficiency but low emissions (NO_X, CO) in the combustion process. NO_X formation is reduced by reducing the amount of nitrogen in contact with oxygen at high flame temperatures.

Oxy-fuel burners are used throughout industry, including the steel and glass sectors. The high velocities of the gases in the burner ensure that the fuel is completely combusted at a lower temperature zone of the flame. An earlier case study in the metal casting industry reviewed the installation of an oxy-fuel melting furnace in an iron foundry. The furnace achieved a reduction

[24] U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy. *Industrial Technologies Program. Energy Tips – Steam – Upgrading Boilers to High-efficiency Burners.*

in energy use and an improvement in operating costs and had a lower initial investment cost than a conventional electric furnace.[25]

The use of oxy-gas direct flame impingement (DFI) is specifically applicable to stainless steel annealing. DFI is based on a large number of small oxy-fuel burners that are positioned in rows close to the steel strip. They are positioned as such in order to determine the oxy-fuel flames that are directly impinging the strips. Production capacity increases after the installation of the DFI oxy-gas unit and improves energy efficiency.[26]

Flue Gas Heat Recovery

Flue gas heat recovery increases efficiency because it extracts energy from the exhaust gases and recycles it back to the process. Significant efficiency improvements can be made to furnaces, kilns, dryers and ovens, even if they are already operating with properly tuned ratio and temperature controls.

For lower- and medium-temperature applications, heat recovery from flue gas can be used to preheat oven burners or heat other media such as makeup air, feed product or ventilation makeup air. The energy saved in heat recovered from the flue gas is related to the temperature difference between the flue gas and the heated medium, and the savings depend upon finding applications where heat recovery is economical and improves the process. Heat or enthalpy wheels are used to recover the heat at a number of facilities. The actual energy savings and costs depend on the heat wheel implemented.

New heat recovery technologies continue to be developed, such as heat wheels with a desiccant core to recover energy, which can operate with low-grade heat in more robust environments. Opportunities vary by subsector; for example, in the food subsector, recovered flue gas can provide heat in the dough-rising stage or can provide hot water for other processes. Payback periods for heat recovery systems in medium- to low-temperature applications, such as ovens and dryers, range between 2.5 and 4 years and are dependent on the type of technology implemented and the application of the recovered heat.[27]

For high-temperature applications, there are four widely used methods: using direct heat recovery to the product; using a recuperator to transfer heat from the outgoing exhaust gas to the incoming combustion air while keeping the two streams from mixing; using a regenerator to store thermal energy for future use; and using a waste heat boiler.

Process Heat Recovery to Preheat Product

Process heat recovery includes using waste heat from industrial processes to heat other processes or utility streams. There is a wide range of heat recovery opportunities, including heat transfer between a heat source and a heat sink, where the heat source and sink could be gas, liquid or solid. With this measure, the recovered process heat is used to preheat products that will be heated in an oven or kiln.

[25] Ernest, Orlando. Lawrence Berkley National Laboratory and the American Council for an Energy Efficient Economy (ACEEE). *Emerging Energy-Efficient Industrial Technologies*. 2000. Report reference number: LBNL 46990.

[26] Gas, L. *State-of-the-art Oxyfuel Solutions for Reheating and Annealing Furnaces in Steel Industry*. 2007. Presentation retrieved from www.linde-gas.com/rebox.

[27] Ernest, Orlando. Lawrence Berkley National Laboratory. *Energy Efficiency Improvement and Cost Saving Opportunities for the Vehicle Assembly Industry*. 2003. Report reference number: LBNL 50939.

Advanced Heating and Process Control

Advanced heating and process controls refer to opportunities to reduce energy losses by improving control systems that govern aspects such as material handling, heat storage and turndown. These controls also include process thermal optimization measures. Energy losses that are generally attributable to system operation during periods of low throughput are addressed. Some advanced controls use a programmed heating temperature setting for part-load operation; they also monitor and control exhaust gas oxygen as well as unburned hydrocarbon and CO emissions. Advanced heating and process controls are often one of the first energy efficiency measures that a facility will implement. Although the measure has achieved a substantial market penetration, a large market still remains.

Insulation

Heat loss can cause a significant reduction in process heating efficiency. Insulation of equipment and pipes increases the amount of energy available for end uses by decreasing the amount of heat lost from the system. New refractory fibre material with low thermal conductivity and heat storage can produce significant improvements in efficiency. Typical applications include installing furnace covers, installing fibre liner between the standard refractory lining and the shell wall or installing ceramic fibre liner over the present refractory liner. Replacing standard refractory linings with vacuum-formed refractory fibre insulation can also improve efficiency. Installing a furnace with refractory fibre liners can reportedly improve the thermal efficiency of the heating process by up to 50 percent.[28]

Insulation removed during maintenance is often not replaced, and older insulation deteriorates with time. To improve the energy efficiency of the system, regular insulation surveys help to identify areas with insufficient insulation. A significant number of facilities do not have regular insulation surveys.

Air Curtains

Air-heat seals at continuous oven and dryer entrances and exits limit heat loss with airflow. Air curtains are generally not applicable to batch operations and are generally not technically feasible for high-temperature processes, such as kilns and furnaces, because of the process layout and the high temperature differential. They are also not feasible if the processes operate as batch processes.

In a typical application, a heat seal draws hot interior air in and compresses it in scroll fans. Centrifugal fans create an air curtain at oven and dryer openings. On these openings, air curtains are normally installed horizontally over the opening and angled slightly inward to contain the hot air. Air-heat seals can be installed as a retrofit or a new installation.

D-5 Refrigeration and Cooling System

High-Efficiency Multiplex Compressors

This measure involves replacing standard-efficiency, stand-alone refrigeration compressors with several (three to five) high-efficiency refrigeration compressors of different capacities connected in

[28] U.S. Environmental Protection Agency. *Wise Rules for Industrial Efficiency: A Toolkit for Estimating Energy Savings and Greenhouse Gas Emissions.* 1998.

parallel. Aside from the energy saved with high-efficiency compressors, significant energy savings are also achieved by operating the optimum combination of compressors to maximize the overall part-load efficiency.

High-Efficiency Chillers

Centrifugal chillers can offer great savings over absorption and other types of chillers, particularly if they are running at full-load or using adjustable speed drive (ASD) controls.

Optimized Distribution System

An optimized distribution system ensures proper refrigerant feed to evaporators without excessive pressure drop, prevents excessive lubricating oil in any part of the system, ensures that the compressor is adequately lubricated, and optimizes refrigerant distribution.

Free-Cooling

Free-cooling involves the use of a cooling tower, when the outdoor temperature is low enough, rather than a chiller in the system. Free-cooling uses cool well/groundwater to pre-cool water/product or to improve the refrigeration cycle.

Floating Head Pressure Controls

With floating head pressure, the system moderates refrigerant flow, depending on outside air temperature and pressure, rather than maintaining a high fixed pressure; this reduces the system's energy requirements.

Premium-Efficiency Refrigeration Control System

A premium-efficiency refrigeration control system is a centralized control system that interfaces with existing controllers to optimally control the operation of each of the compressors, condensers and evaporators. It can also interface with power metering to achieve demand control.

Smart Defrost Controls

Smart defrost controls, in which sensors are used so that defrost is initiated only when necessary and terminated just when the fin block is clear of ice, are more efficient than timed defrosting because they adjust to the varying levels of ice build-up that normally occur.

Doors, Covers and Curtains

Upgraded covers, curtains and doors can seal the cooled space and reduce the amount of cooling energy that is lost to the outside environment, thereby reducing the cooling load on the refrigeration equipment.

Insulation of Refrigeration System

Insulation on the refrigerant piping and other parts of the system reduces the heat that the refrigerant absorbs from any environment other than the refrigerated area.

D-6 Pumps, Fans and Other Motors

Optimized Duct Design to Improve Efficiency

Ducts can be optimized by reducing the number of 90° angles in the system as well as by optimizing the cross-sectional area of the duct and eliminating unnecessary duct systems, thereby reducing the friction and pressure that the pumps and fans must overcome.

Impeller Trimming

Impeller trimming provides an opportunity to customize the size of a pump or fan without having to buy expensive new parts.

D-7 Air Compressor System

Premium Efficiency ASD Compressor

Premium efficiency air compressors have high-efficiency components and come with built-in ASD control that allows the compressor output to match the plant air demand. They use a variety of advanced technologies, including frictionless compression, magnetic bearings and digital controls. The compressor has only one main moving part with two stages of centrifugal compression and has the potential to incorporate an economizer. These compressors achieve the highest overall efficiencies for compressors (e.g., a Turbocor product).

Replace Pneumatic Motors with Mechanical

Many smaller tools such as grinders use pneumatic motors. These motors can often be changed to high-speed electric motors, stepping motors or to direct current motors with a significant reduction in energy use.

Low-Pressure Blower to Replace Compressed Air

This option replaces compressed air with low-pressure blowers in low-pressure applications; air is thereby provided using less electrical energy.

Optimized Sizing and Pressure of Compressor System

Typically, compressors that do not exactly meet the design conditions of the process or system are selected. Replacing an oversized compressor with one that more closely matches the system requirements reduces energy consumption.

Optimized Distribution System

Distribution system upgrades involve optimizing air storage to reduce pressure fluctuations and air piping redesign to reduce friction losses. The piping redesign can also reduce the system pressure drop and lower the set point at the air compressors. Removing, or capping, unused pipes will help the system operate at a lower pressure and reduce air demand.

Optimized Sizes of Air Receiver Tanks

The optimization of air storage can reduce pressure and fluctuations in compressed air demand at the compressor.

Cooler Air From Outside for Makeup Air

Outdoor air may be used as makeup air, because it is normally cooler than the air in the compressor room or other parts of the facility. It takes less energy to compress cool air than it does to compress warm air.

Adjustable Speed/Variable Frequency Drive

This option is a standard compressor coupled with an electronic adjustable-speed drive. In order to meet variable compression loads, compressor speed can be adjusted, which will improve the part-load efficiency of the compression cycle.

Sequencing Control

Sequencing control systems can operate the compressors so that the larger compressor is base-loaded (always on), the mid-sized compressors are used as needed to increase supply, and an ASD compressor acts as the trim compressor (provides for the variable component of the process air demand).

Air-Leak Survey and Repairs

Regular inspection of air leaks and repairs can result in substantial savings through reduced compressed air demand. Air leaks may be eliminated by upgrading air connectors, hoses and other associated parts.

D-8 Process Specific

Optimized Process Controls

Overall process efficiency can be increased by optimizing control systems that govern aspects such as material handling, heat storage and turndown, and thermal optimization measures.

D-9 Heating, Ventilation and Air Conditioning (HVAC)

Solar Walls

Solar walls use solar energy to preheat outside air before it is introduced into a plant. The warmed air can be distributed as is, further heated in a building's primary heating system or used as combustion air for industrial furnaces. Because the air entering the system is already warm, less energy is required to heat it further.

Solar walls are typically made of dark metal cladding, usually unglazed corrugated aluminum, which is mounted over a south-facing wall. Sunlight hitting the cladding warms the air near its surface; the air is then drawn through thousands of small perforations in the cladding into a narrow space between the wall and the building. The heated air rises to an overhanging canopy plenum and is drawn into the facility by fans and dampers. A solar wall is virtually maintenance-free; it has no liquids or moving parts other than the ventilation system fans.

Radiant Heaters

Radiant heating equipment is designed to provide comfort heating through the application of radiant heat transfer. Radiant heaters emit heated infrared rays, which are absorbed by objects such as floors, equipment or people. Infrared heat rays do not warm the air although the air immediately surrounding the "heated" objects is warmed by the increased temperature of the objects. These systems are very efficient, compared to convection-type heaters, and can use significantly less natural gas than a natural-gas-fired convection heating system. Radiant heating technology is mature and data indicate that close to one third of the potential market is already captured.

Ground Source Heat Pump

Ground source heat pumps provide more efficient heating and cooling than standard or high-efficiency air source heat pumps by using a heat source/sink.

These systems can either be closed-loop or open-looped. An open-loop pump uses an available water supply as the heat source/sink. These systems can only be used where water sources are easily available and allowed to be used for this purpose.

Closed-loop systems use the thermal storage capacity of the ground for space heating and cooling. In closed-loop systems, horizontal or vertical piping networks are placed below the ground as heat exchangers (heat source/sink). Water is pumped through the network and exchanges heat with the heat pump's refrigerant.

Ventilation Optimization

Ventilation optimization includes optimizing the volume of air brought into a facility as well as matching the load required at different times. It is also possible to use interlocking ventilation air supply and exhaust during the operation of the process in cases where ventilation air is required to ensure that air quality requirements are met while the process is in operation.

Ventilation Heat Recovery

In a ventilation heat recovery system, a heat exchanger or enthalpy wheel recovers heat from ventilation air about to be exhausted. The recovered heat is used to preheat fresh makeup air that is brought in to replace the exhausted air, thus reducing the amount of energy used to heat the air to the required temperature.

Air Compressor Heat Recovery

Typically, the warm exhaust gas produced by plant air compressors is discharged outside the building. Using this exhaust during the winter to replace outside makeup air can significantly reduce the cold makeup air supply. Installing a duct that joins the compressor gas exhaust to the existing plant air distribution system ensures that the warm air is distributed evenly through the plant. During summer months, the exhaust gas from the compressors will still need to be vented outside the building.

Automated Temperature Control

Automatic temperature controls allow the temperature in different areas to vary according to a schedule in order to save energy during times when a space need not be heated or cooled as much. These controls may also prevent individuals from manually changing the temperature settings.

Destratification Fans

The air temperature in large, high-ceiling storage rooms can become stratified (i.e., air is layered at different temperatures at different levels). Destratification fans are high-volume, low-speed fans that mix the air and eliminate stratified layers of temperature in large spaces. The amount of energy these types of fans use is comparable to conventional, small ceiling fans, but since fewer fans are required, the total energy required is reduced. High-volume, low-speed destratification fans have been on the market for a number of years and are in the early stages of market penetration.

Warehouse Loading Dock Seals

Warehouse loading dock seals provide a barrier between the back of a docked truck and the edges of the loading dock opening. An improper seal may result in drafts and loss of heat from the warehouse.

Air Curtains

A large amount of heat may be lost between the time loading dock doors are opened and a truck is docked. An air curtain at the loading dock door acts as a thermal barrier and lowers the amount of energy lost through the opening. Air curtains generate a jet of high-velocity air that separates the two sides of the jet, forming a screen or curtain. The air curtain should be activated as soon as the loading dock door is opened and then stopped once it is closed, in order to conserve energy. Air curtains can either be heated or unheated, depending on the application requirement.

D-10 Lighting

High-Efficiency Lights and Ballasts

As lighting technology continues to improve, the efficiency levels of both lights and ballasts continue to improve. Maximum increases in efficiency are attained by replacing both the bulb and the ballast.

High-Efficiency Lighting Design

In an efficient lighting design, areas are only lit according to the occupancy requirements, and lighting is reduced in overly lit areas. For example, task lighting may be used in place of higher-intensity ambient lighting.

Automated Lighting Controls

Automated lighting controls are used to reduce the amount of time that a space is illuminated while it is vacant. Controls can include occupancy sensors, photocells and timers.