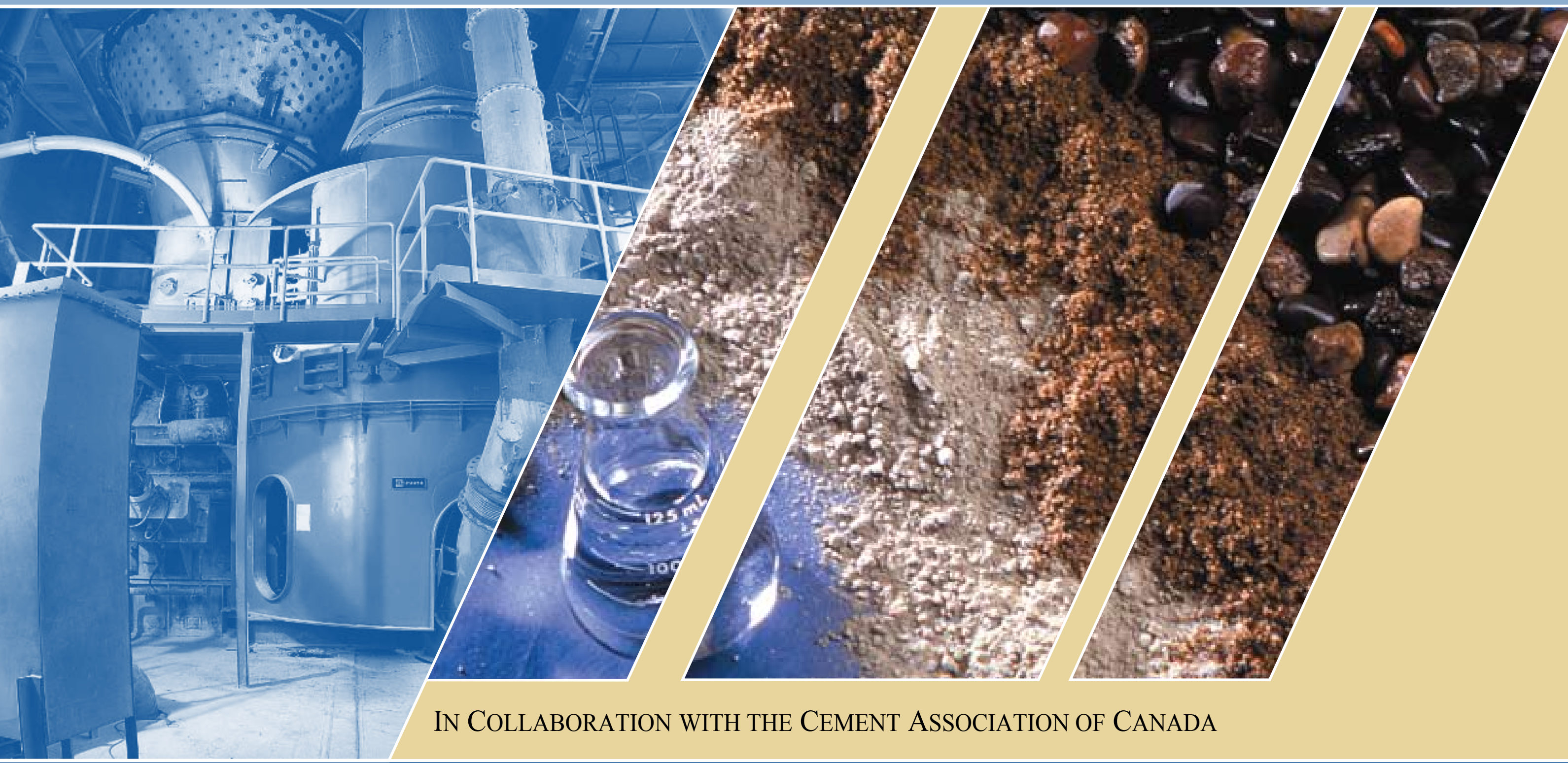
Natural Resources Canada — Ressources naturelles Canada

ecoENERGY
an ecoACTION initiative

Canadian Cement Industry Energy Benchmarking

SUMMARY REPORT



In Collaboration with the Cement Association of Canada

CIPEC

Canada

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

Canadian Industry Program for Energy Conservation
c/o Natural Resources Canada
580 Booth Street, 12th floor
Ottawa ON K1A 0E4

Tel.: 613-995-6839
Fax: 613-992-3161
E-mail: cipec-peeic@nrcan-rncan.gc.ca
Web site: oee.nrcan.gc.ca/cipec

or

Cement Association of Canada
502–350 Sparks Street
Ottawa ON K1R 7S8

Tel.: 613-236-9471
Fax: 613-563-4498
E-mail: headquarters@cement.ca
Web site: www.cement.ca

Library and Archives Canada Cataloguing in Publication

Energy Performance Benchmarking and Best Practices in Canadian Cement Manufacturing Sector

Text in English and French on inverted pages.
Title added t.p.: Analyse comparative de la consommation d' énergie dans l'industrie canadienne du ciment.

Issued by the Canadian Industry Program for Energy Conservation.

Cat. No. M144-213/2009 (Print)   Cat. No. M144-213/2009E-PDF (On-line)
ISBN 978-1-100-50372-1   ISBN 978-1-100-14036-0

1. New hotdisc reactor, the Ecofurnace, at the Ciment Québec Saint-Basile plant, Quebec. Photo courtesy of the Cement Association of Canada
2. Concrete components. Photo courtesy of the Cement Association of Canada.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOREWORD

With support from Natural Resources Canada (NRCan), the Cement Association of Canada (CAC) commissioned an energy benchmarking study of Canada's Portland grey cement industry in 2007. The study builds on other sector benchmarking initiatives undertaken by NRCan's Office of Energy Efficiency. This report summarizes the outcomes of the CAC study and is based on a more comprehensive consultant's report that includes detailed recommendations prepared for the CAC.[1]

This analysis of energy efficiency performance in the cement sector represents a broad and comprehensive review of energy management practices, technical practices and overall energy efficiency performance.

Through this study, the CAC developed benchmarks and sophisticated tools that provide a comprehensive roadmap for facilities and companies to improve energy management practices and performance. The benchmarking tools will allow the industry to conduct regular self-assessments of energy performance in a manner consistent with internationally recognized quality management principles and best practices.

The study determined that the overall energy efficiency of the cement sector was relatively good, with a median **energy efficiency index** (EEI) value of 76, compared with a theoretical best practices plant with a value of 100. The relatively high level of overall energy efficiency is attributed to facilities and organizations that are already actively engaged in energy management programs.

However, despite overall high EEI, many facilities have a low electricity EEI, and significant potential for improved electricity use efficiency exists. Benchmarks for EEI, management best practices (MBPs) and technical best practices (TBPs) that were developed for individual facilities identified opportunity areas. Even in facilities with an overall high benchmark, opportunities exist for more energy efficiency improvements and cost savings.

The benchmarking results show that the most significant potential for increased implementation of energy MBPs is in **project planning and development** and in **measurement and reporting**. The assessment of both the TBPs and energy use efficiency identifies that the **fuel and raw materials preparation** and **cement and feedstock** process steps have significant potential to yield important energy efficiency benefits for the sector.

The **kiln process** consumes approximately 90 percent of the energy used in the cement manufacturing sector. This includes 99 percent of the thermal energy use and more than a third of total electricity consumed in the manufacturing process. Even a small improvement in kiln performance will yield substantial energy and cost savings for the individual facility and the entire industry.

Cement manufacturing facilities showed significant differences in **electric energy** efficiency. Electric energy accounts for a substantial portion of energy cost in the cement manufacturing sector, and improved electric energy efficiency may result in notable cost savings.

---

[1] *Canadian Cement Industry Benchmarking – Final Report,* Report prepared for Cement Association of Canada by Marbek Resource Consultants Ltd. in association with Ecofys and Cement Etc., Inc., 2008.

The energy use is dominated by coal and petroleum coke consumption, which accounts for more than 80 percent of the purchased energy. Increasing the proportion of alternative, renewable and low-carbon energy sources can contribute significantly to reducing greenhouse gas emissions from cement manufacturing.

The study demonstrates that relationships exist between a facility's implementation of energy MBPs and TBPs and the energy efficiency of its operations. Operations that implemented the most energy MBPs also implemented the most TBPs. These facilities consume less energy per unit of production than their peers.

1 INTRODUCTION

Lafarge Saint-Constant plant, Quebec

2

1 INTRODUCTION

1.1 ABOUT THE CANADIAN CEMENT INDUSTRY

The Cement Association of Canada (CAC) comprises eight companies that operate 1 white[2] and 15 Portland grey cement manufacturing facilities across Canada. The members of the association produce 98 percent of the cement manufactured in Canada.

Regionally, cement production is concentrated in central Canada. Ontario (50 percent) and Quebec (17 percent) have more than 65 percent of the industry's capacity. The CAC is allied with the United States-based Portland Cement Association (PCA) and all CAC members are also members of the PCA.

The cement industry is a key contributor to Canada's economic and social development. In 2006, the industry produced more than 14.3 million tonnes (t) of cement with a value of more than $1.7 billion and provided more than 2000 jobs.[3] The industry's total production is more than 16.7 million t when supplementary cementing materials such as fly ash and slag are included.

The cement manufacturing industry realized an 11 percent increase in energy efficiency per tonne of cement produced between 1990 and 2006 and a corresponding reduction in greenhouse gas (GHG) intensity of 6.4 percent.[4] However, the industry recognizes that further energy efficiency improvements are required to

- reduce energy costs and maintain industry competitiveness in a period of ever-increasing international competition
- make further progress in reducing the industry's environmental footprint

1.2 ABOUT ENERGY BENCHMARKING AND THIS SUMMARY REPORT

Energy benchmarking provides a means through which an industry and facilities within that industry can assess their performance against

- recognized best practices
- the performance of their sector peers
- external competitors in the same industry
- energy consumers in other industrial sectors

[2] The Federal White Cement plant in Woodstock, Ontario, is excluded from the benchmarks due to major differences in raw materials and fuels usage between the manufacturing of Portland white cement and Portland grey cement, which is produced at the balance of the manufacturing sites in Canada.
[3] Cement Association of Canada (2008), *Canadian Cement Industry 2008 Sustainability Report*
[4] Ibid.

Energy benchmarking can play an important role in supporting improved energy practices by

- identifying and communicating best practices
- motivating plants that operate below the benchmark to improve to the level of their peers
- identifying areas that need improvement in all facilities, including facilities that are the best performers

The study involved all 15 Portland grey cement manufacturing facilities operated by CAC member companies (see Table 1.1).

Table 1-1 Participating Cement Manufacturing Facilities

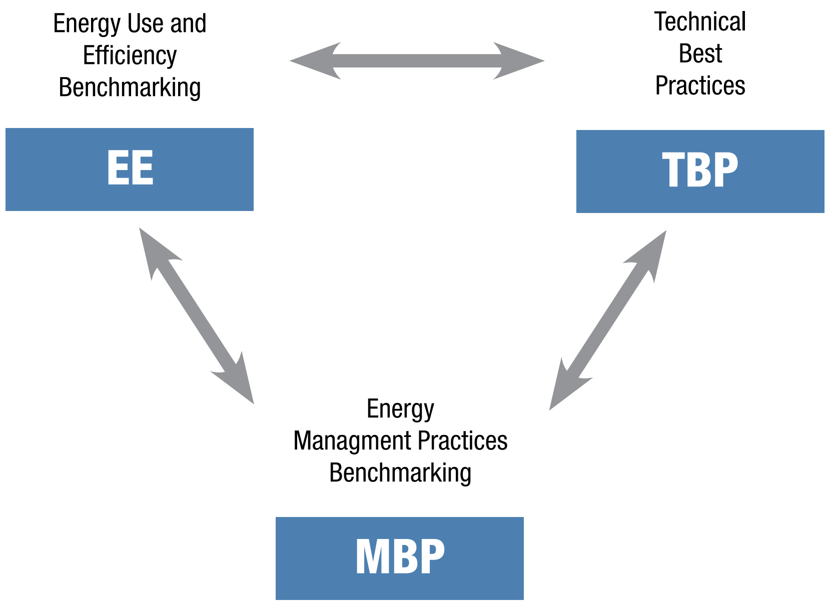
Company	Facility
Ciment Québec Inc.	Saint-Basile, Quebec
Essroc (Italcementi Group)	Picton, Ontario
Lafarge Canada Ltd.	Brookfield, Nova Scotia Saint-Constant, Quebec Bath, Ontario Woodstock, Ontario Exshaw, Alberta Kamloops, British Columbia Richmond, British Columbia
Lehigh Hanson Canada	Edmonton, Alberta Delta, British Columbia
Holcim (Canada) Inc.	Joliette, Quebec Mississauga, Ontario
St Marys Cement Inc.	Bowmanville, Ontario St. Marys, Ontario

The study analyzed the industry's performance in three critical areas that influence overall energy use:

- management practices
- technical practices
- energy efficiency performance

The assessment of these three areas presents a broad and holistic view of energy practices in the cement manufacturing sector.

Figure 1-1 Critical areas influencing overall energy use



In addition to this summary report, reports have been produced that document the performance of each of the 15 facilities against the benchmarks developed as part of the study.

The CAC views this important study as the first step in developing and implementing a comprehensive action plan to improve energy performance in the sector. Now that benchmarks exist and current performance has been assessed against those benchmarks, future studies can assess and report progress in improving energy performance within the Canadian Portland grey cement sector.

1.3 STUDY METHODOLOGY

The study was initiated by developing individual analytical models to assess performance in each of the three aspects of energy performance:

- energy management practices
- technical practices
- energy efficiency performance

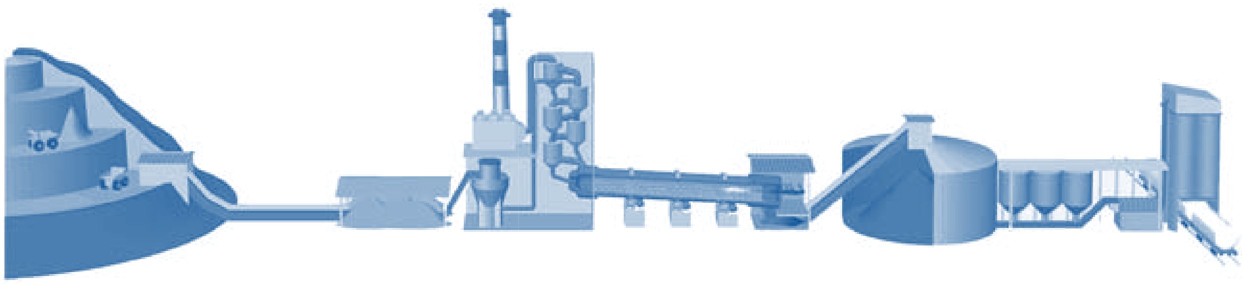
The models were developed by reviewing recognized analytical models for energy management and technical practices broadly, and for cement manufacturing more specifically. These externally referenced models were developed by international bodies, standard setting organizations and government agencies that have responsibilities for energy and energy efficiency in the manufacturing sectors.

Within each model, energy practices were further assessed across each of the key processes and activities associated with cement manufacturing (see Figure 1-2):

- on-site raw materials preparation and transport
- on-site fuel preparation and transport

- clinker production (kiln operation)
- storage
- finish grinding
- packing and on-site transport to loading terminals
- operation of plant-wide support systems (e.g. compressed air systems, heat, lighting)

Figure 1-2 Cement manufacturing process



Source: Holcim (Canada)

Quarrying	Raw Materials Preparation	Clinker Production	Cement Grinding and Distribution
Limestone and small amounts of sand and clay are extracted, usually from a quarry located near the cement manufacturing plant.	The extracted materials are analyzed, blended with additional mineral components depending on the type of limestone available, and finely ground for futher processing.	The materials are heated in a kiln reaching a temperature of 1,470˚C. The heat transforms the materials into a molten product called clinker, which is then rapidly cooled.	The clinker is stored and then finely ground. Gypsum is added to control setting time, along with supplementary cementing materials, such as fly ash or slag, to obtain a fine powder called cement, with the desired properties of strength and chemical resistance.

More than 70 aspects of energy performance in the cement manufacturing sector were analyzed, including all energy inputs to the cement manufacturing process: electricity, fuel oil, natural gas, coal, petroleum coke and other alternative fuels.[5]

Survey instruments were developed to gather the information to assess performance within each of the three models. The survey instruments and models were tested at two cement manufacturing facilities. After revisions, the survey instruments were distributed to all 15 cement manufacturing facilities. Then supervised data collection, review and analysis proceeded. Performance benchmarks were developed for each indicator, and each facility's performance was assessed against the benchmarks.

The performance benchmarks were set at the 75th percentile, which means that for each performance indicator, 25 percent of the sector's facilities met or exceeded the benchmark. This approach is consistent with the approach taken by Natural Resources Canada's Office of Energy Efficiency benchmarking studies and the U.S. Environmental Protection Agency's ENERGY STAR® for Cement Manufacturing initiative. Draft facility reports were submitted to the facility operators for review and validation. After data error corrections were made, final performance benchmarks and the final facility and sector-wide reports were prepared.

[5] Quarrying activities and/or any of the above activities that take place at locations other than the main cement production site were excluded from the analysis. Also, analysis of only on-site electricity consumption was considered, rather than the total primary energy consumption associated with off-site electricity generation.

2 ENERGY USE IN CEMENT MANUFACTURING

Holcim Mississauga plant, Ontario

8

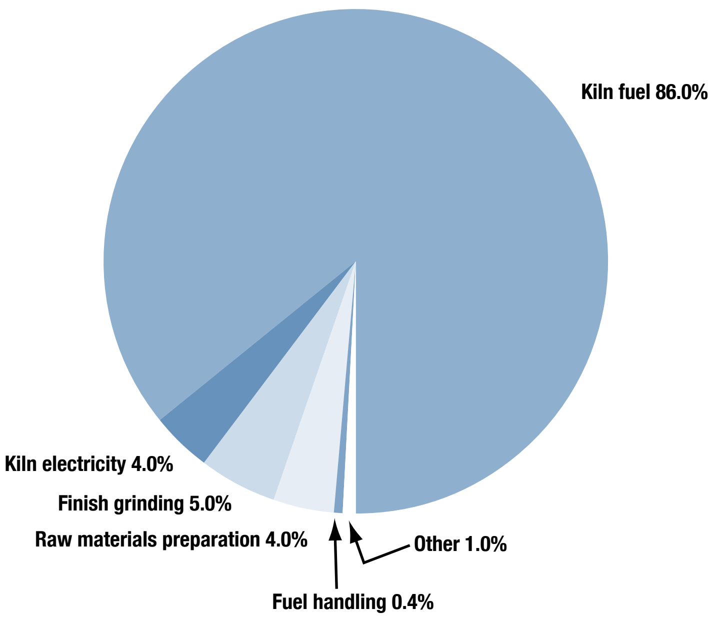
2 ENERGY USE IN CEMENT MANUFACTURING

Cement manufacturing is an energy-intensive process that consumed more than 61 000 terajoules of energy in Canada in 2006, of which 95 percent was thermal energy and 5 percent was electric energy.

The kiln process consumes more than 90 percent of the cement manufacturing energy. The remaining 10 percent is consumed in almost equal amounts by activities related to fuel and raw materials preparation, grinding of clinker and the blending of materials to prepare the finished cement product.

Figure 2-1 provides a breakdown of the energy use.

Figure 2-1 Total Energy for Cement Manufacturing Sector by Process Step, 2006



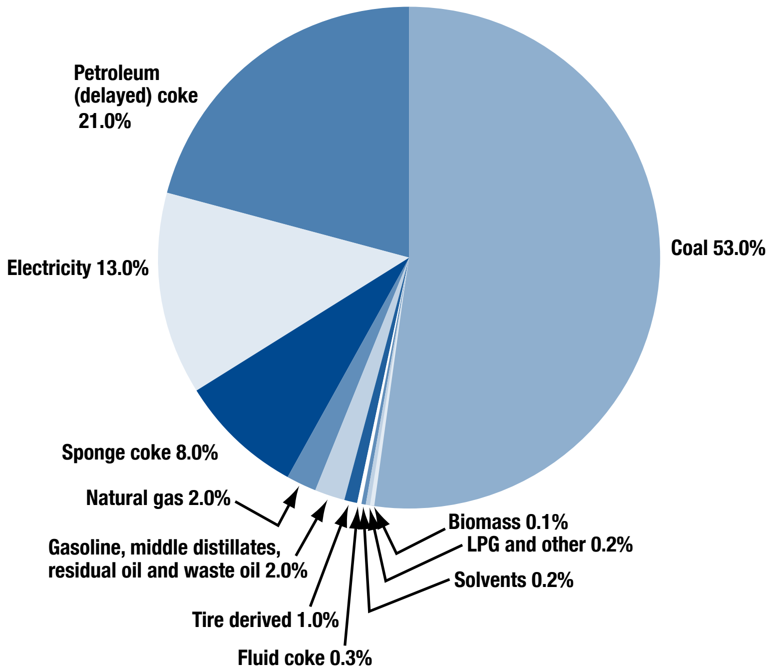
The sum of these energy inputs is about 39 percent of the annual operating costs of a cement manufacturing facility, making energy the largest cost component. It is important to note that although electricity accounts for only 13 percent of the energy inputs, it is almost 50 percent of the energy costs of a typical cement plant.[6]

The cement industry relies heavily on carbon-intensive fossil fuels. Coal (53 percent)[7] and petroleum coke products (29 percent) account for more than 82 percent of energy consumption (Figure 2-2). Natural gas (used mostly as a start-up fuel), liquid petroleum products and waste oil products contribute 4 percent of total energy requirements, while tire-derived fuels and other alternative energy sources contribute about 2 percent.

[6] Statistics Canada, *Annual Survey of Manufacturers* (2004).

[7] A comparison of Canadian energy costs on a per-unit basis demonstrated that coal continues to be significantly less expensive than the other forms of energy used by the cement industry. Natural Resources Canada (2006), *Canada's Energy Outlook: The Reference Case 2006*. Ottawa, Ont.

Figure 2-2 Total Energy for Cement Manufacturing Sector by Energy Source, 2006



Key findings from this high-level overview of energy inputs to the cement manufacturing sector include the following:

- Due to the significant quantity of energy consumed by the kiln process, energy efficiency opportunities in the kiln process have, in theory, the **greatest potential** to translate into real energy, greenhouse gas (GHG) and cost savings for the industry. Even minor improvements in the kiln process can potentially deliver significant energy and cost savings over an annual operating cycle.
- Energy efficiency opportunities in electrically driven systems have the potential to achieve substantial cost savings for the industry.
- Canada's contribution of alternative and renewable energy sources to cement manufacturing lags behind that of other nations in the Organisation for Economic Co-operation and Development. Many countries in the European Union substitute from 30 percent to 83 percent of the energy sources for cement manufacturing.[8] Increasing the proportion of alternative, renewable and low-carbon energy sources can contribute significantly to reducing GHG emissions from cement manufacturing.

[8] Cement Association of Canada (2008), *Canadian Cement Industry 2008 Sustainability Report*. European countries included in this range are Netherlands (83 percent), Switzerland (48 percent), Austria (46 percent), Germany (42 percent), Norway (35 percent), France (34 percent) and Belgium (30 percent).

3 ENERGY MANAGEMENT PRACTICES

Vertical roller mill, Mississauga, Ontario reduces Holcim (Canada) Inc. greenhouse gas intensity

3 ENERGY MANAGEMENT PRACTICES

3.1 INTRODUCTION

Energy management – the process and practice of treating energy as a strategic resource – is an influential determinant of a plant's energy performance. Best practices in energy management have a high level of commitment, awareness, organization and action.

Typically, plants that exhibit energy management best practices (MPBs)

- have broad awareness of the benefits of energy efficiency
- collect and use information to manage energy use
- integrate energy management into their overall management structure
- provide leadership on energy management through dedicated staff and a committed energy efficiency policy
- have an energy management plan for the short- and long-term

3.2 STUDY APPROACH

The Cement Association of Canada study reviewed and analysed existing energy management models[9] and identified 28 MBP areas of relevance to the cement manufacturing sector (see Table 3-1).

A survey was conducted at every cement manufacturing facility to ascertain the degree to which the identified best practices are currently employed in the sector. To gain multiple perspectives, three respondents at each facility were involved in the survey for their facility:

- a plant manager or process engineer
- a corporate lead on energy issues
- a representative of the corporate executive management team

The MBP score was calculated as an average of the three survey results.

[9] The energy management models that contributed significantly to the definition of the competencies were developed by Natural Resources Canada's Office of Energy Efficiency, United Kingdom's Carbon Trust, United States' ENERGY STAR® and Australia's EPA Victoria and Sustainable Victoria.

Table 3-1 Energy Management Best Practice Elements by Category

MBP Categories	MBPs
Commitment	Promotion Policy Guidelines and Procedures
Planning	Formal Planning Support for Planning Implementation
Organization	Energy champion Responsibility and accountability Energy Leader Energy Team
Project Development	Capacity building Identification of Opportunities Energy Management Best Practices
Financing	Commitment Planning Integrating energy management with project approval
Measurement and Reporting	Monitoring System Reporting Use of Monitoring Results
Communication	Extent Frequency Awareness and Participation

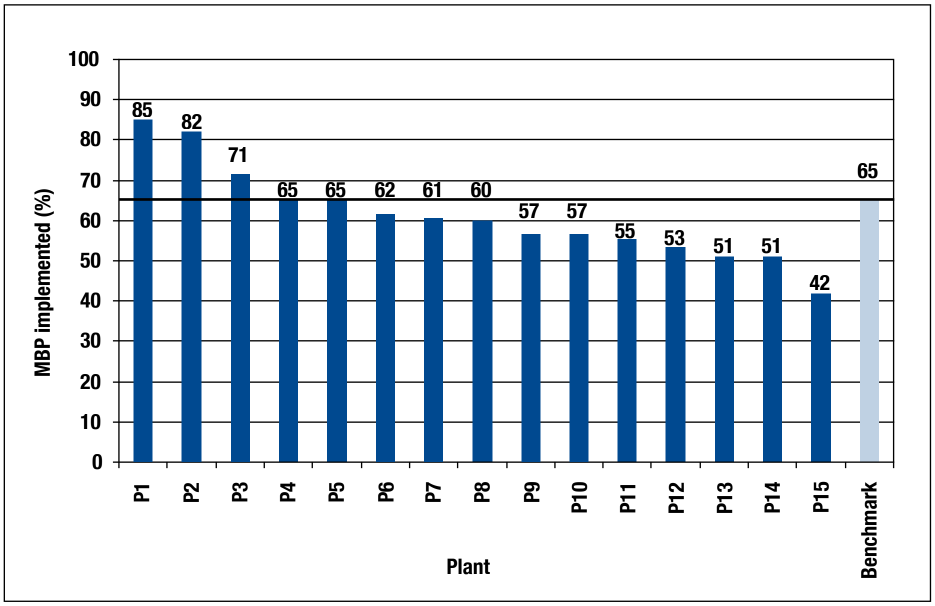
3.3 ENERGY MANAGEMENT PRACTICES RESULTS

The review of MBPs identified a benchmark value of 65 percent for the cement manufacturing sector. This means that 25 percent of cement facilities employ at least 65 percent of the identified energy MBPs, and the remaining facilities employ less than 65 percent of the MBPs (see Figure 3-1).

The results showed that significant potential exists in the cement sector to improve management practices in support of improving energy efficiency, especially because only two facilities received a rating greater than 75 percent for management practices implementation.

The study showed a strong relationship between the implementation of MBPs and the overall energy efficiency at the cement facilities. The four plants that ranked the highest in overall energy efficiency (see Chapter 5) are among the five plants that rated highest in MBP implementation.

Figure 3-1 Energy Management Best Practices Scores



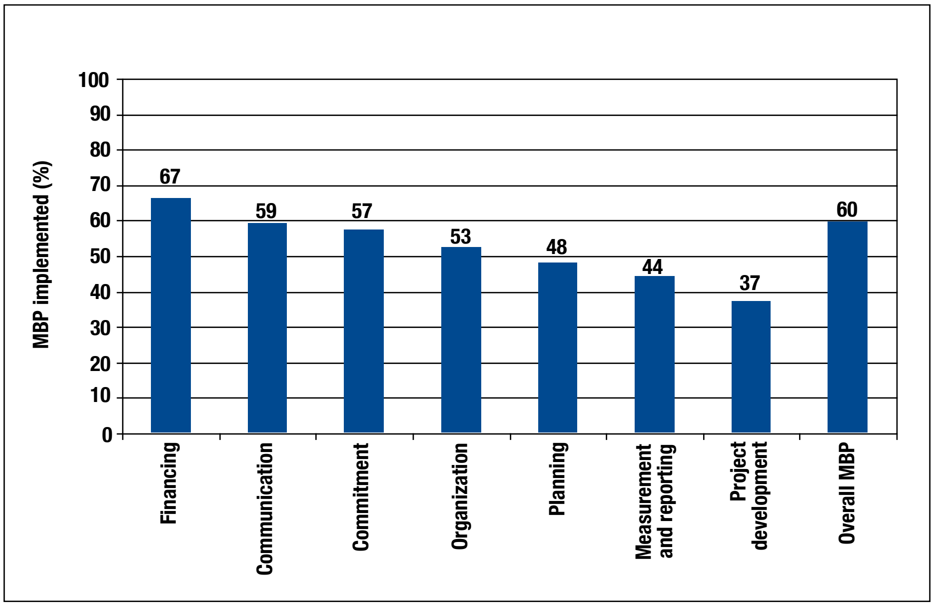
The survey of MBPs exhibited a fairly narrow range of implementation scores because 70 percent of the facilities scored between 50 and 65 percent. MBP scores from plants that belong to the same organizations also tended to cluster together. This fact suggests that corporate-specific policies and guidelines generally direct the implementation of practices in cement sector facilities. Benchmarking studies in other industrial sectors have shown that this situation is not always the case, and that in some cases, overall MBP scores of plants within the same organization differ significantly.

For individual MBP categories, the analysis of the survey results showed that the cement sector emphasizes the financing and communication performance aspects of energy management (Figure 3-2). Consistent with other Canadian industry studies,[10] the analysis showed that the cement sector has the largest improvement potential in energy management practices areas related to project development, planning and measurement and reporting.

[10] Nova Scotia industry data from *Energy Management Potential Analysis and Best Practices Benchmarking in the Nova Scotia Industrial and Manufacturing Sector*, Report by Canadian Manufacturers & Exporters in association with Marbek Resource Consultants Ltd. and Neill & Gunter Limited (Stantec), 2007.

New Brunswick industry data from *Energy Performance Benchmarking and Best Practices in the New Brunswick Industrial and Manufacturing Sector*, Report by Canadian Manufacturers & Exporters in association with Marbek Resource Consultants Ltd. and Neill & Gunter Limited (Stantec), 2006.

Figure 3-2 Median Energy Management Best Practices Scores



For more details, see Appendix A, page 30.

4 TECHNICAL PRACTICES

St Marys Cement Bowmanville plant from the West Side Creek Marsh Conservation Area, Ontario

4 TECHNICAL PRACTICES

4.1 INTRODUCTION

The second aspect of energy performance that was analyzed is the implementation of technical best practices (TBPs) in cement manufacturing facilities. TBPs are production processes, systems, activities and equipment that can contribute to improvements in plant energy efficiency (e.g. using adjustable speed drives on kiln and/or roller mill fans).

4.2 STUDY APPROACH

The Cement Association of Canada study included an extensive review of Canadian and international literature to identify TBPs applicable to the cement manufacturing sector. The review identified 39 TBPs that were categorized across the five main cement manufacturing subprocesses:

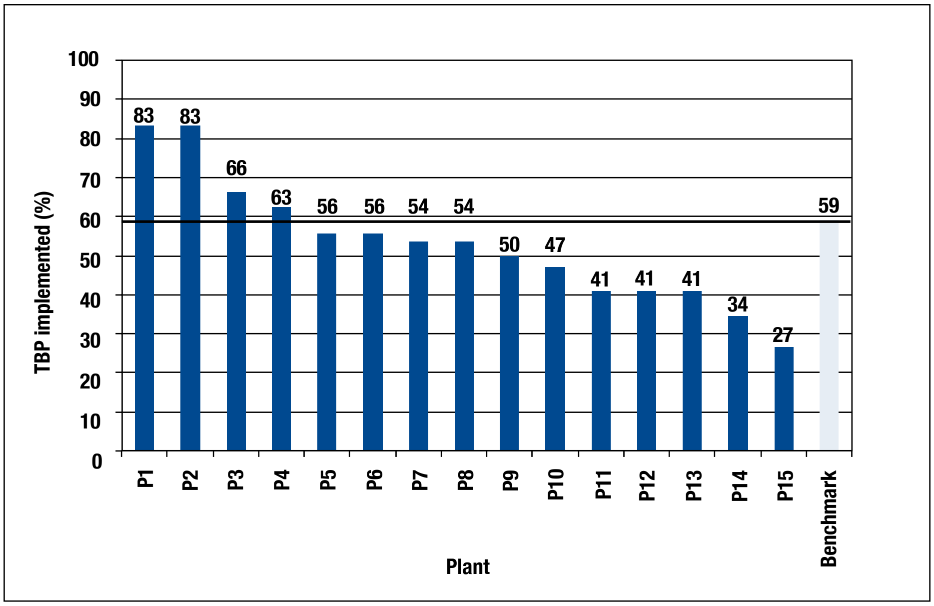
- fuel and raw materials preparation
- clinker production
- finish grinding
- cement and feedstock
- general measures

A survey instrument was developed at each facility to assess the applicability of the identified practices and the degree of implementation (i.e. full, partial or not implemented).

4.3 TECHNICAL PRACTICES RESULTS

The review of TBPs identified a benchmark value of 59 percent for the cement manufacturing sector. This means that 25 percent of cement facilities employ at least 59 percent of the identified TBPs, and the remaining facilities employ less than 59 percent of the TBPs (see Figure 4-1).

Figure 4-1 Penetration of Applicable Technical Best Practices by Plant

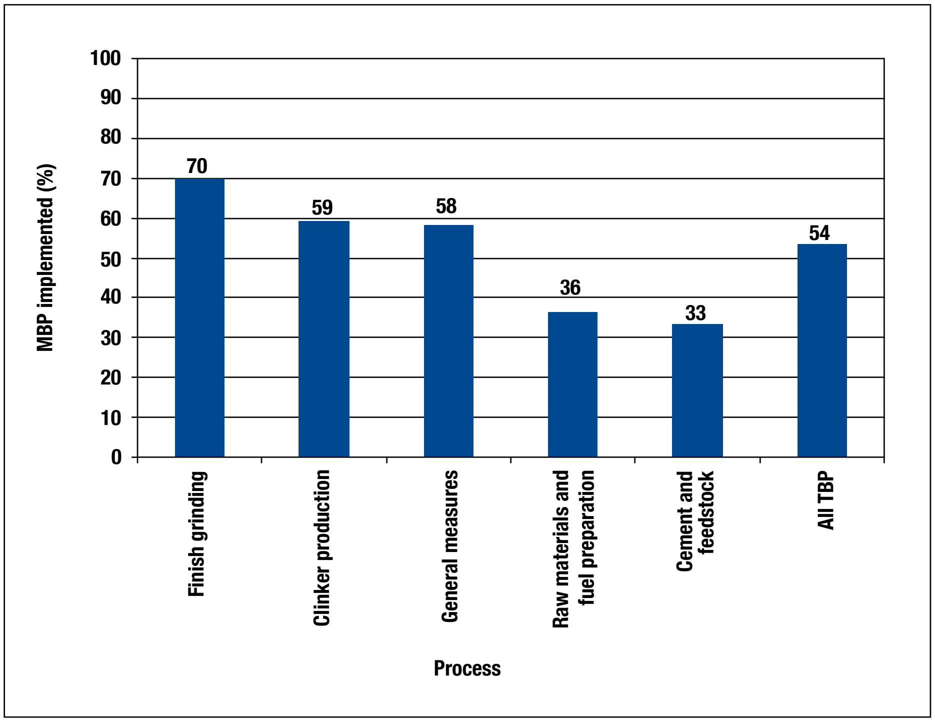


The results showed that significant potential exists in the cement sector to improve technical practices in support of improving energy efficiency, especially because only two facilities received a good rating for technical practices implementation (a rate greater than 75 percent).

The study showed a statistical correlation between the implementation of TBPs and overall energy efficiency. This means that the energy efficiency of a plant increases when the number of TBPs implemented at the plant increases. In contrast to the assessment of management practices, the assessment of technical practices showed a wide spread of implementation scores (70 percent of the plants have scores between 34 and 63 percent) and an insignificant relationship between TBP implementation scores among facilities from the same organization.

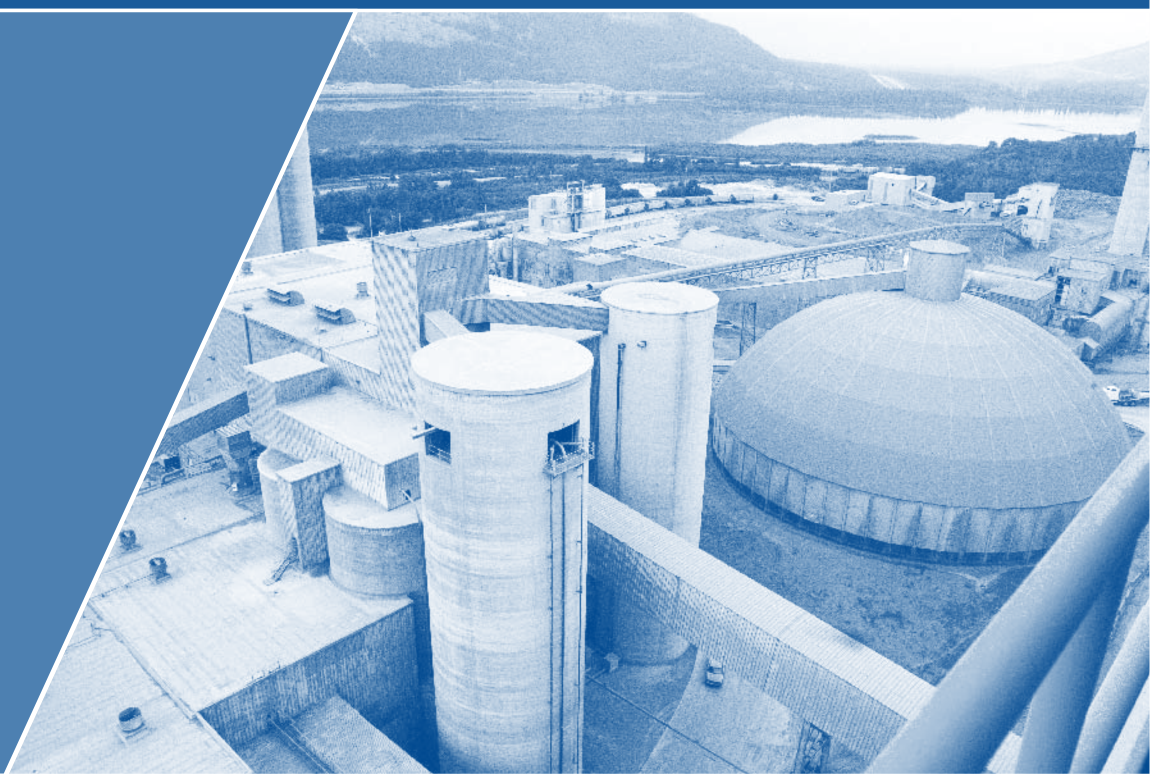
The benchmarking process demonstrates that the cement sector emphasizes the energy efficiency practices in the finish grinding process – a process that consumes significant quantities of electrical energy. The study showed, however, that opportunities exist to improve energy efficiency by employing additional TBPs in process steps associated with fuel and raw materials preparation and in cement and feedstock composition and handling. The TBPs include improving the transportation and blending of cement and addressing the use of additives (see Figure 4-2).

Figure 4-2 Median Technical Best Practice Scores



For more details, see Appendix B, page 34.

5 ENERGY EFFICIENCY INDEX



Lafarge Exshaw plant, Alberta

5 ENERGY EFFICIENCY INDEX

5.1 INTRODUCTION

The third aspect of energy performance that was analyzed is the amount of energy used in cement manufacturing facilities. Assessing the amount of energy used, while considering production and structural influences, provides a performance indicator of energy efficiency.

5.2 STUDY APPROACH

The Cement Association of Canada study included an extensive review of Canadian and international literature to identify potential metrics for measuring overall plant and process-specific energy efficiency. To provide capacity for ongoing in-depth analysis of energy efficiency in the cement manufacturing sector, an energy efficiency benchmarking tool was developed that evaluates energy performance at both the plant level and process level.

The tool calculates such indicators as total energy intensity (gigajoule per tonne [GJ/t of cement); fuel intensity (GJ/t of cement or clinker); electricity intensity (kilowatt hour per tonne of cement); and an energy efficiency index.

The **Energy Efficiency Index** (EEI) allows a meaningful direct comparison between plants with significant structural differences (e.g. wet kiln and dry kiln processes). A theoretical "best practice" plant was constructed, normalizing as much as possible for structural differences, and was given an EEI value of 100.

The energy efficiency was analyzed for

- the performance of the entire plant
- raw meal preparation process
- kiln process
- finish grinding process

Energy use and production data at each manufacturing facility were collected and compared with the theoretical best practices facility. Some facilities performed better than the theoretical best practices plant and attained an EEI value greater than 100 for some process steps.

5.3 OVERALL RESULTS

Analysis of the results showed that the cement sector facilities are operating relatively efficiently, and the overall EEI benchmark was established at 82. This means that 25 percent of the plants achieved at least this relatively high rating. Nine of the 15 facilities achieved a "good practices rating" of at least 75 (see Figure 5-1).

Despite this relatively high performance, considerable opportunity exists for improving energy efficiency because there is a substantial difference between the performance of the lowest performers and the relatively high industry benchmarks within each process step.

When the adjustments for structural differences are ignored, the participating plants have average total energy intensities of 4.2 GJ/t of cement and 4.5 GJ/t of clinker. The most efficient plant required only 50 percent as much energy to produce each tonne of clinker as the least efficient plant.

In the cement manufacturing sector, the **kiln process** uses 90 percent of the energy used and can be expected to have the largest impact on the plant-level EEI. Although cement plants have a high EEI benchmark (85) for the kiln process, it is important to prioritize efforts in this area because a small improvement in the kiln process can potentially result in a large reduction in energy use. The review of technical best practices (TBPs) showed that significant room for improvement remains in the kiln process.

The benchmarking analysis indicated that the sector's **raw meal preparation** processes have the lowest EEI benchmark, at 76 percent (see Figure 5-2). This process step was also identified as having a significant potential for increased TBPs implementation.

Figure 5-1 Total EEI and Total Energy Intensity by Plant

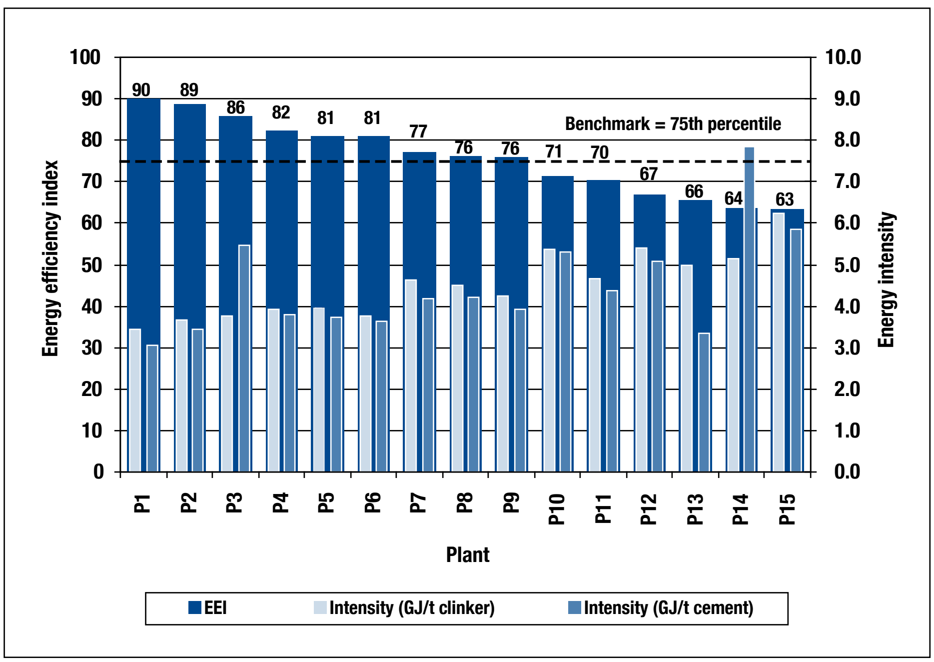
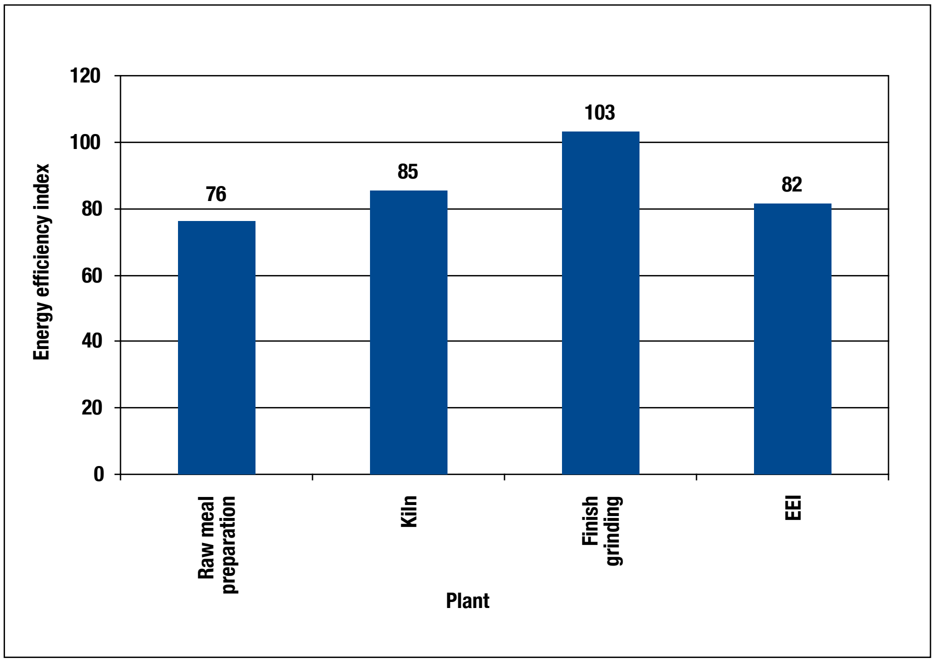


Figure 5-2 Median Energy Efficiency Scores by Process



5.4 ELECTRICITY RESULTS

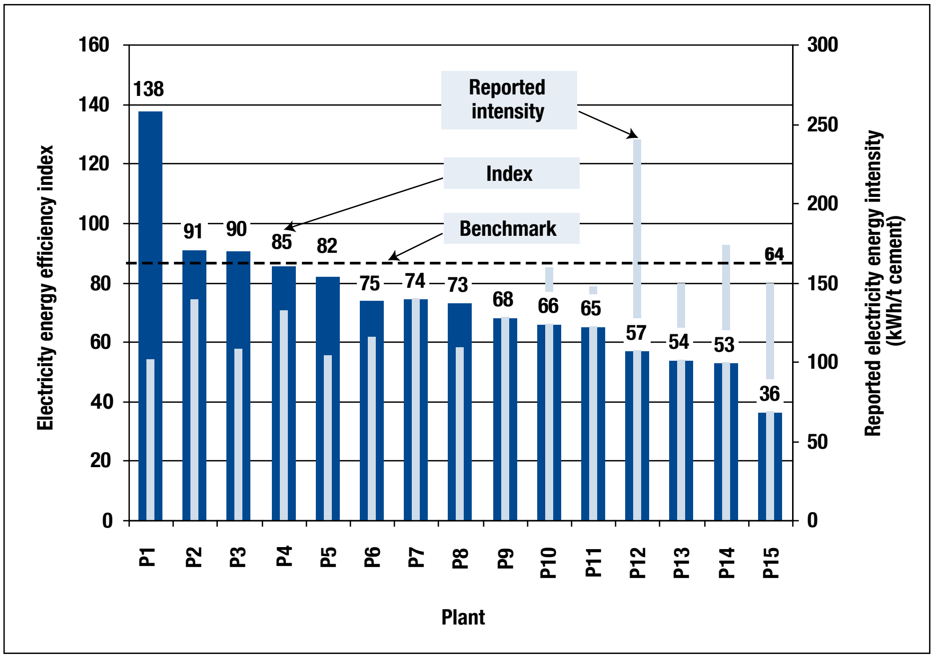
An assessment of electric energy use showed significant differences between facilities. While the best performing plant has an electricity EEI of 138 (against a best practice value of 100), the worst performing facility has an index of 36 (see Figure 5-3).

Electric energy is almost 50 percent of energy costs, but only 13 percent of energy use in the cement manufacturing sector. Improved electricity management is likely to realize significant cost savings but have a limited impact on the already high overall energy efficiency indices of the plants.

When the adjustments for structural differences are ignored, the analysis showed that the most efficient plant, in terms of electricity consumption, consumed only a third of the electricity per tonne of cement produced in comparison with the least efficient plant.

At the process level, the assessment again identified that the sector's **fuel and raw materials preparation** and the **cement and feedstock** process steps have the greatest opportunities for improvement.

Figure 5-3 Electricity EEI and Energy Intensity by Plant



For more details, see Appendix C, page 37.

6 REFERENCES

Cement bags

6 REFERENCES

Cement Association of Canada, *Canadian Cement Industry 2008 Sustainability Report*. 2008.

Marbek Resource Consultants Ltd., Ecofys, Cement Etc., Inc., *Canadian Cement Industry Benchmarking – Final Report*, Cement Association of Canada. 2008.

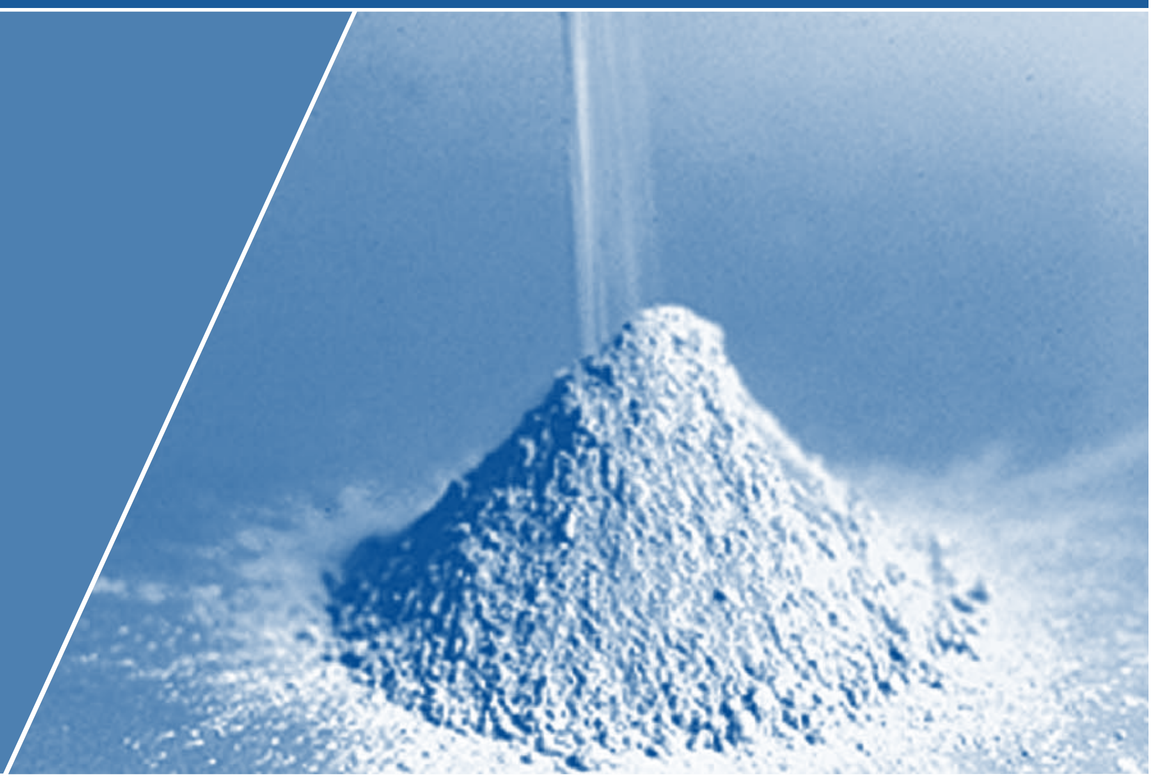
Marbek Resource Consultants Ltd., Neill and Gunter, *Energy Management Potential Analysis and Best Practices Benchmarking in the Nova Scotia Industrial and Manufacturing Sector*, Canadian Manufacturers & Exporters, 2007.

Marbek Resource Consultants Ltd., Neill and Gunter, *Energy Performance Benchmarking & Best Practices in New Brunswick Industrial and Manufacturing Sector*, Canadian Manufacturers & Exporters, 2006.

Natural Resources Canada, *Canada's Energy Outlook: The Reference Case 2006*.

Statistics Canada, *Annual Survey of Manufacturers*. 2004.

APPENDICES



Cement

APPENDIX A: ENERGY MANAGEMENT BEST PRACTICES DETAILED RESULTS

Figure A-1 Implementation of MBPs – Commitment by Plant

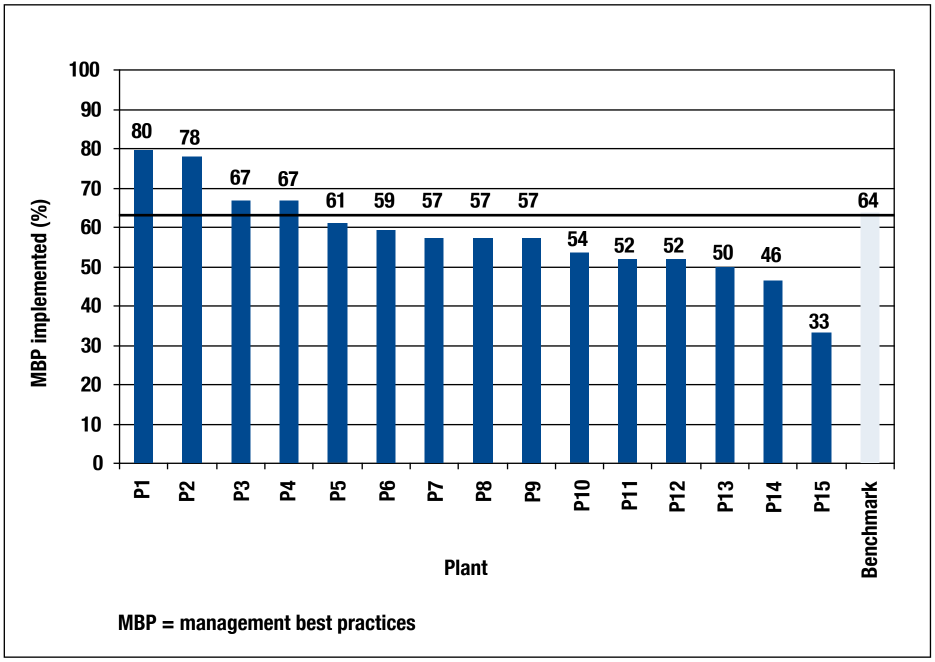


Figure A-2 Implementation of MBPs – Planning by Plant

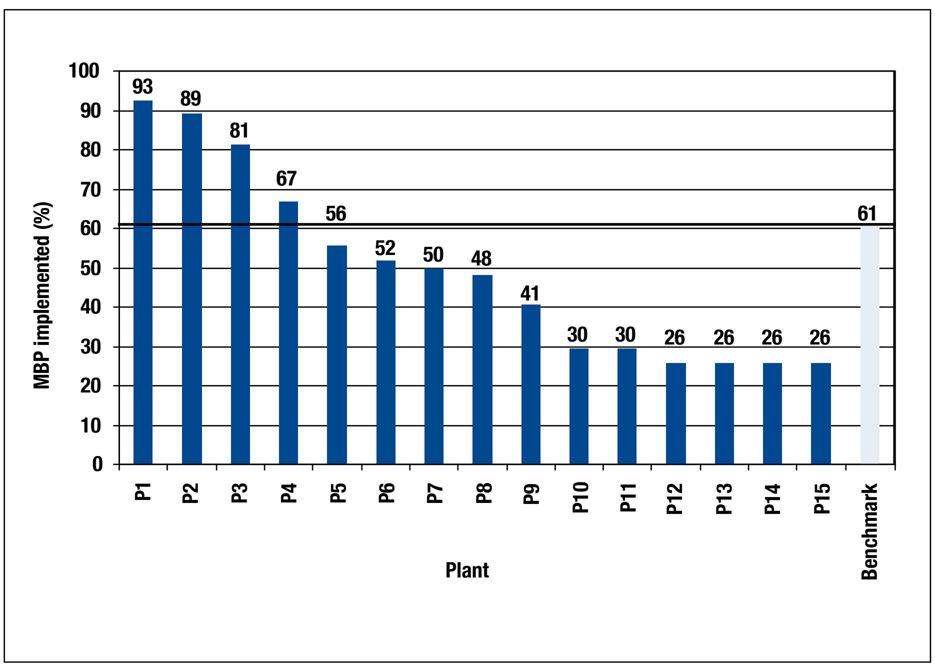


Figure A-3 Implementation of MBPs – Organization by Plant

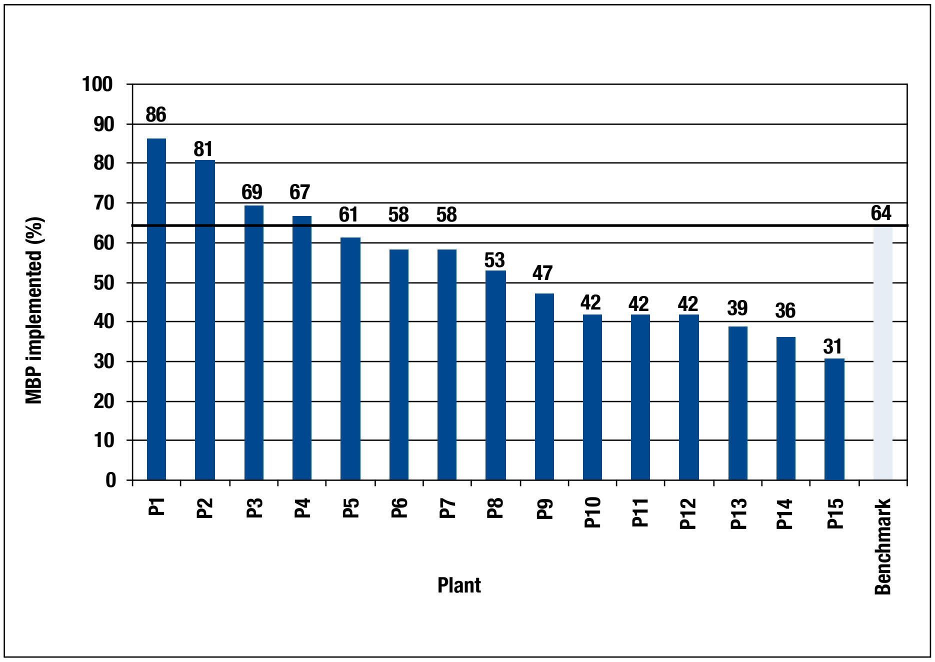


Figure A-4 Implementation of MBPs – Project Development by Plant

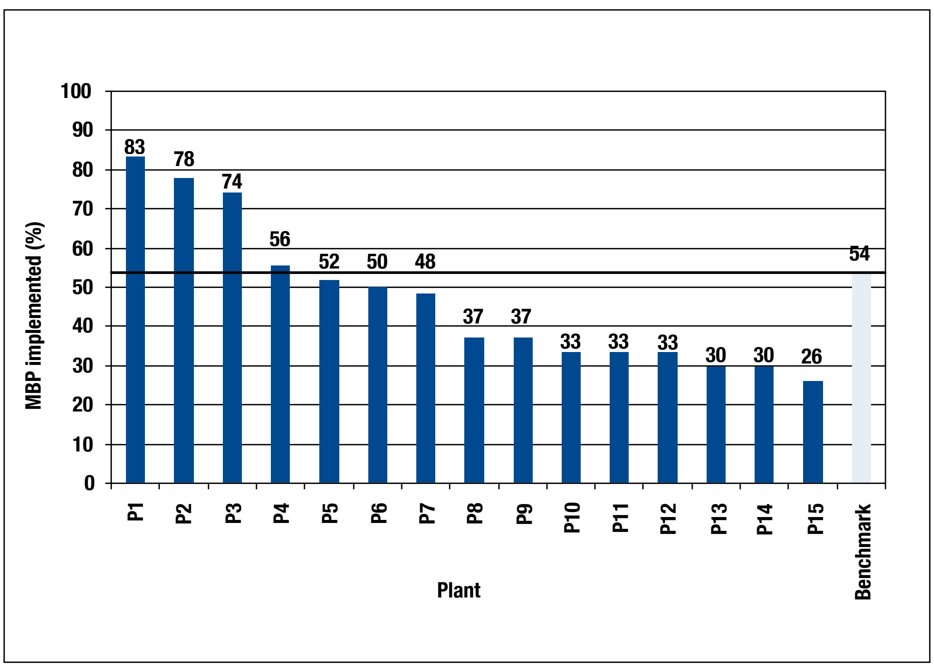


Figure A-5 Implementation of MBPs – Financing by Plant

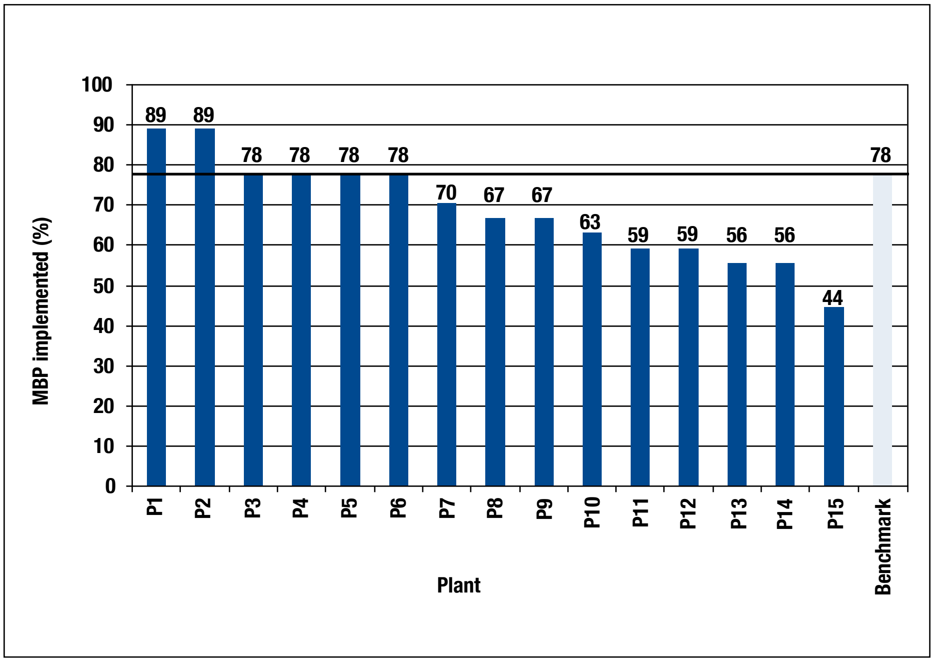


Figure A-6 Implementation of MBPs – Measurement and Reporting by Plant

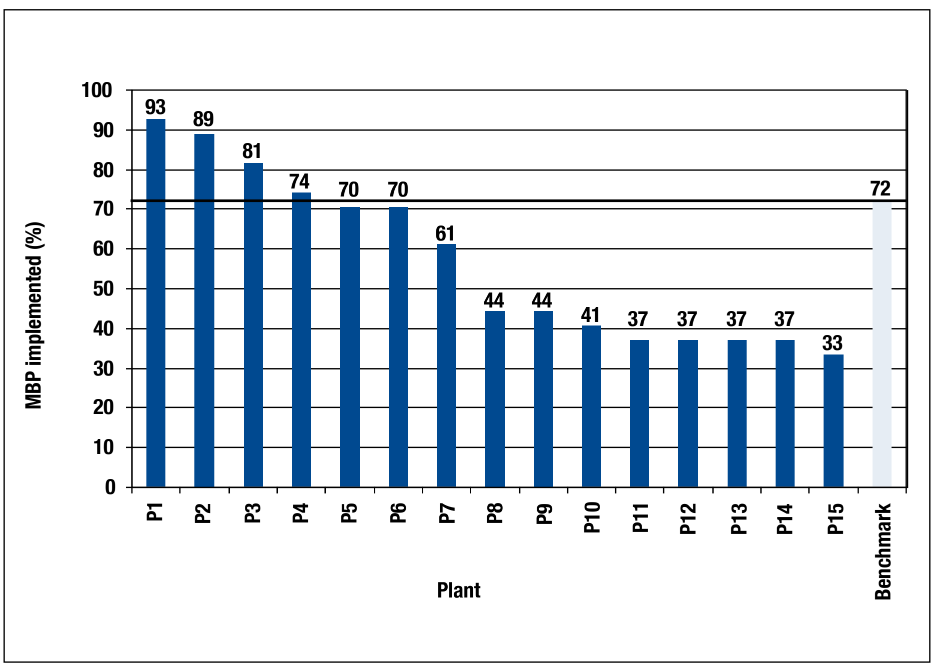
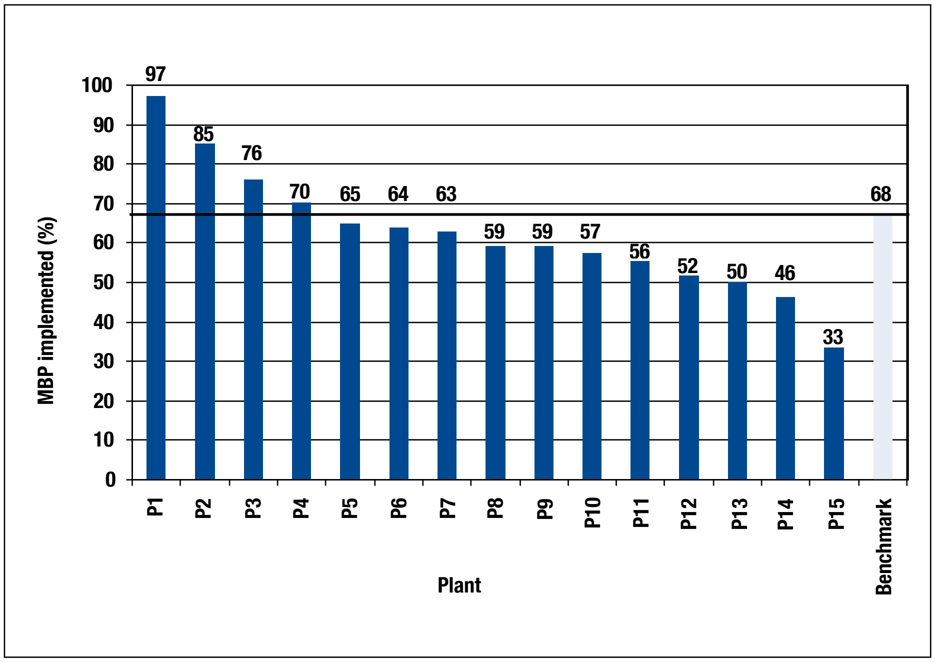


Figure A-7 Implementation of MBPs – Communication by Plant



APPENDIX B: TECHNICAL BEST PRACTICES DETAILED RESULTS

Figure B-1 Implementation of TBPs – Raw Materials and Fuel Preparation by Plant

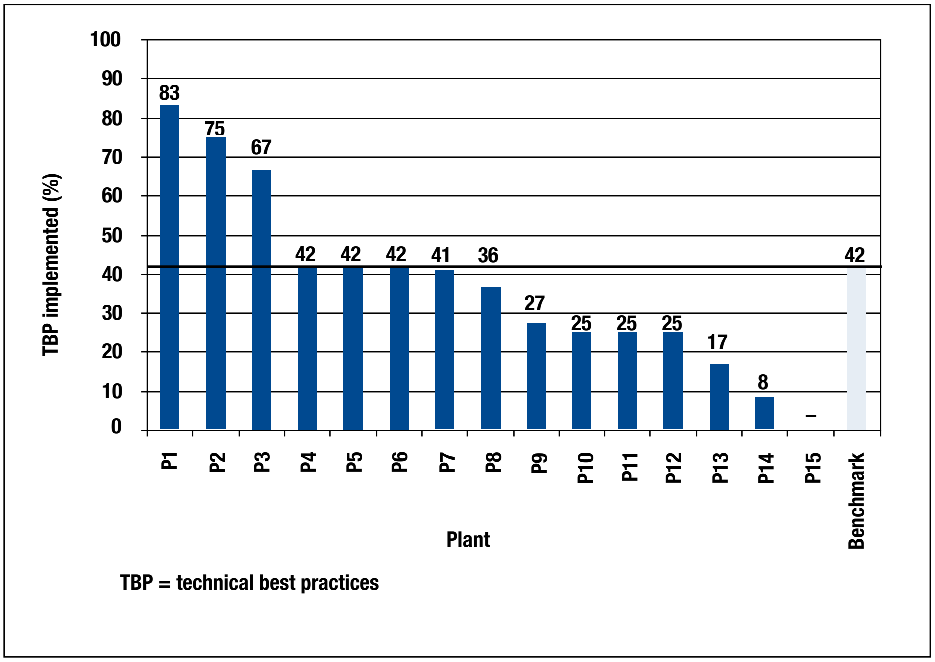


Figure B-2 Implementation of TBPs – Clinker Production by Plant

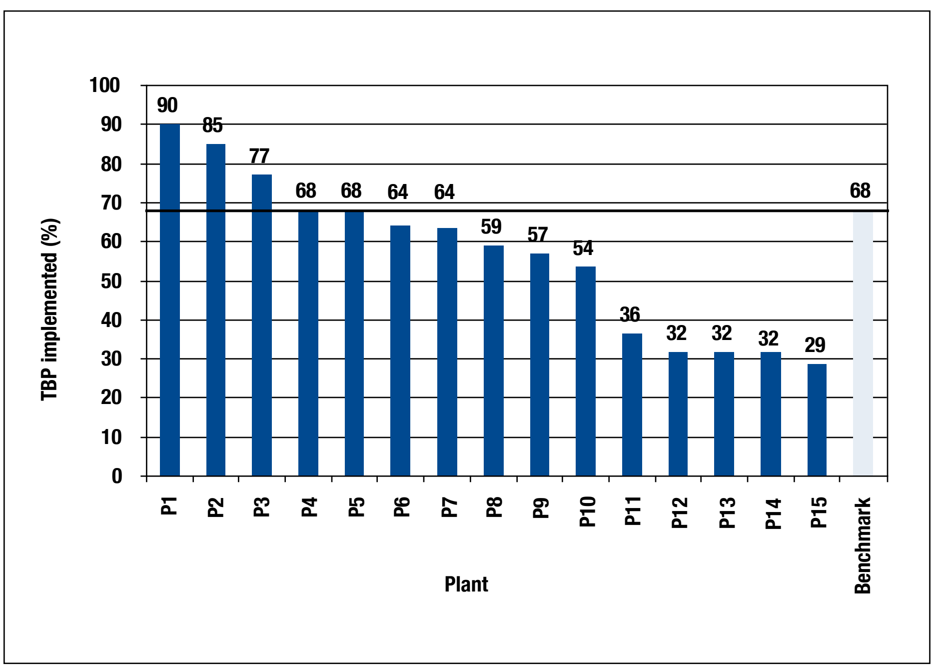


Figure B-3 Implementation of TBPs – Finish Grinding by Plant

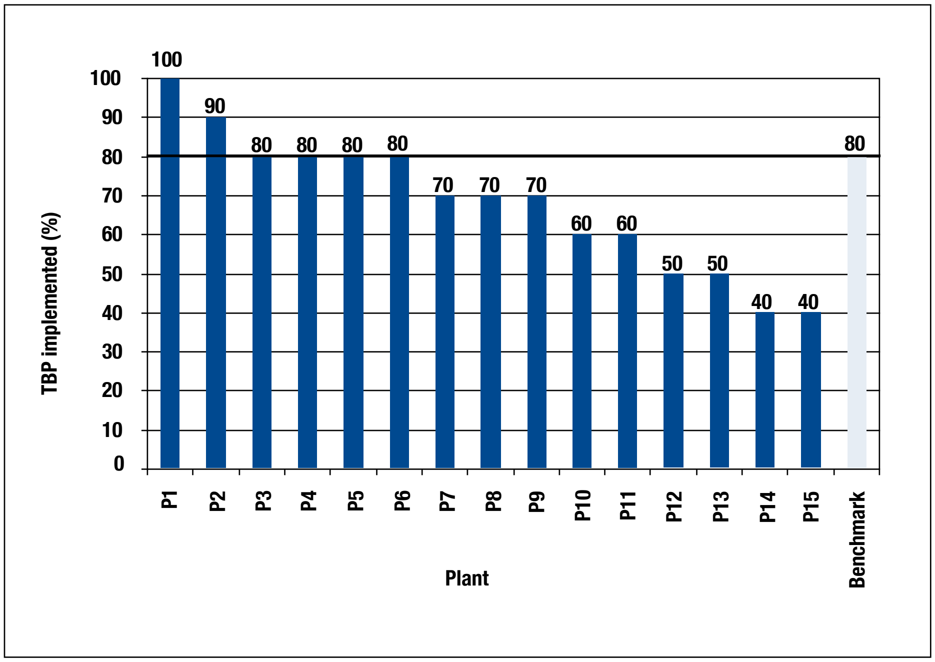


Figure B-4 Implementation of TBPs – Cement and Feedstock by Plant

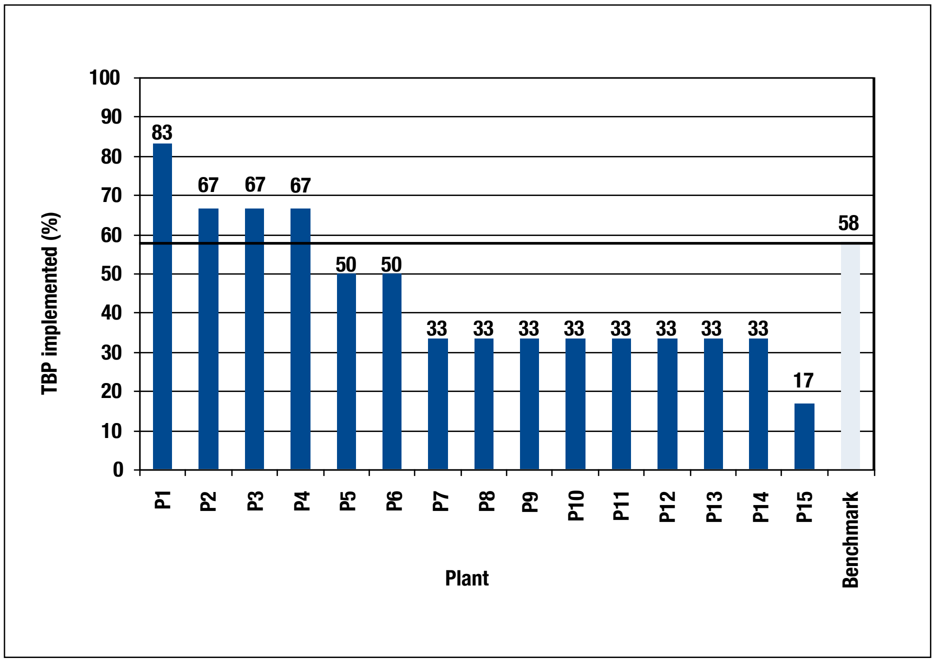
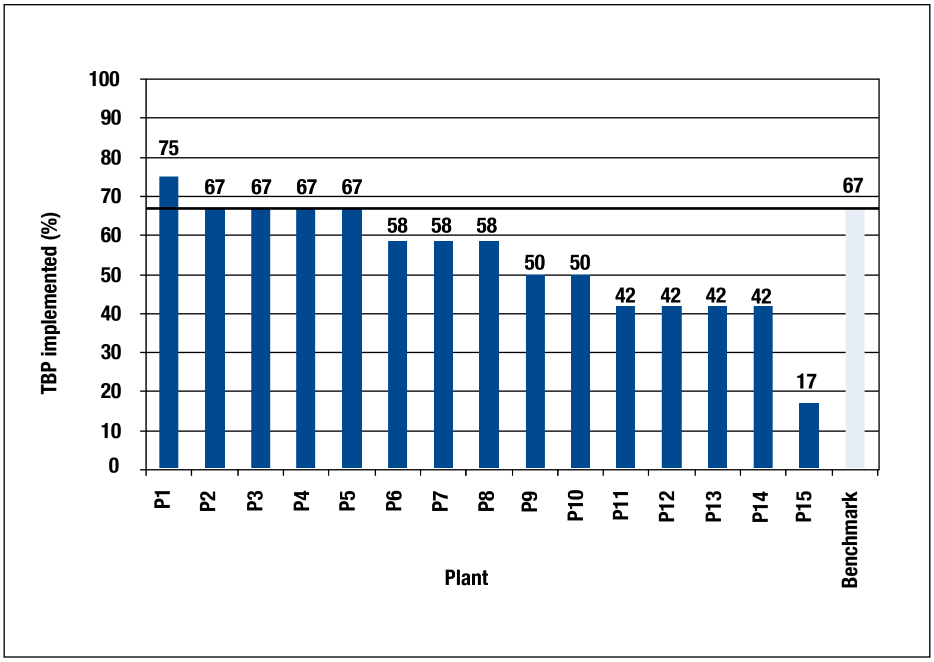


Figure B-5 Implementation of TBPs – General Measures by Plant



APPENDIX C: ENERGY USE AND EFFICIENCY DETAILED RESULTS

Figure C-1 Raw Meal Preparation EEI by Plant

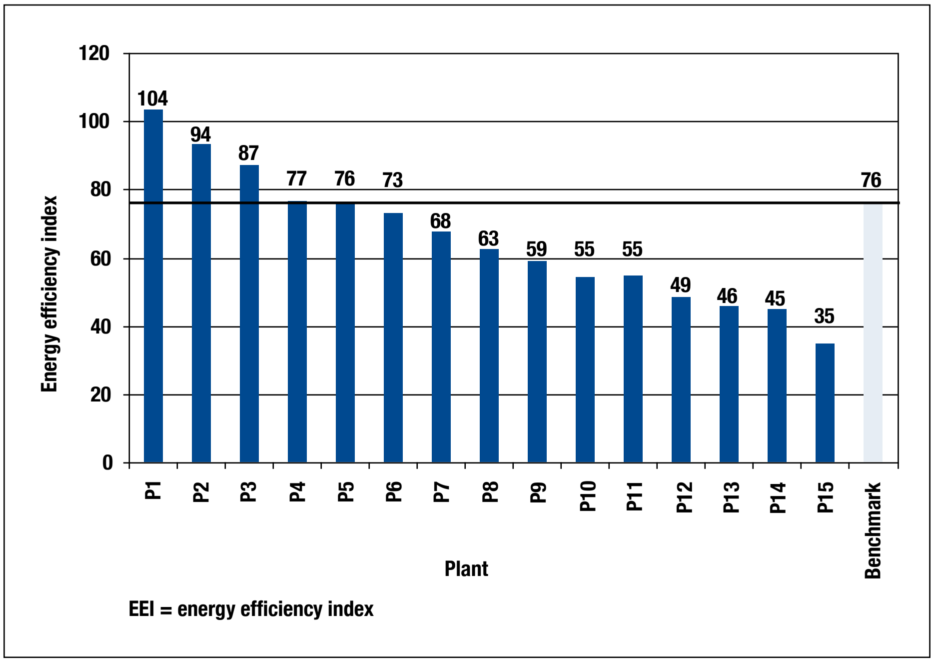


Figure C-2 Kiln EEI by Plant

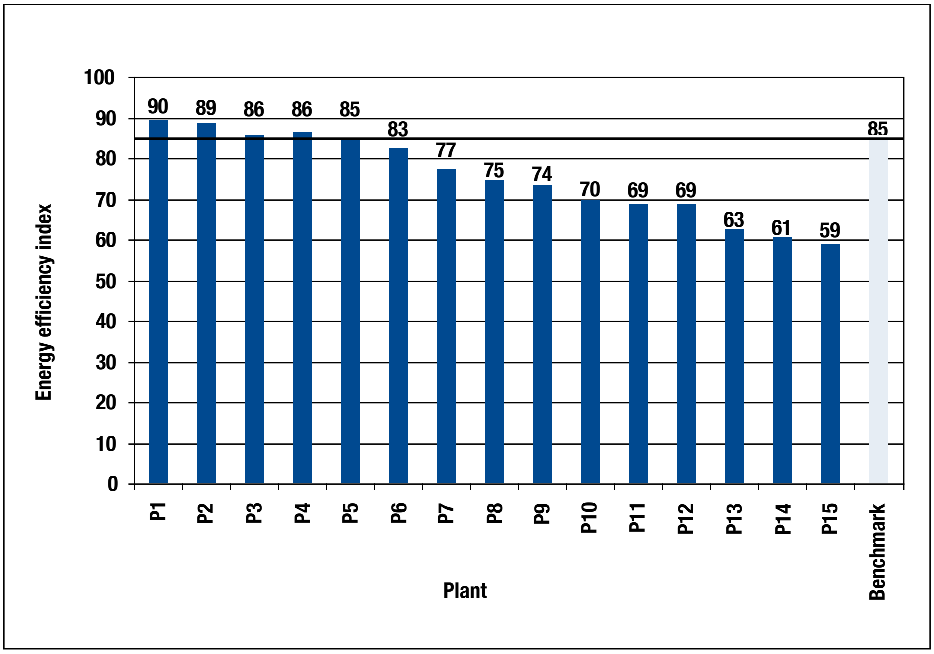


Figure C-3 Finish Grinding EEI by Plant