Integrated Benchmarking Moves from Uncertainty to Solutions

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ABSTRACT

The Cement Association of Canada commissioned an innovative energy benchmarking study that used an integrated approach to benchmark: the implementation of (1) energy management best practices and (2) technical best practices, and (3) the energy use and efficiency in all fifteen Canadian Portland grey cement manufacturing facilities. This paper describes the methodology and results of the integrated energy benchmarking approach, and illustrates the importance of good energy management practices in managing costs and energy. The analysis shows that energy management practices are key to the successful implementation of energy efficiency as a sustained effort, and that benchmarking can be used to define not only performance results, but also to delineate management conclusions.

Background

As an energy intensive industry, energy efficiency has always been important to the Canadian cement manufacturing industry. Energy constitutes about 40% of Canadian cement manufacturing production costs and about 82% of the energy is from carbon intensive fossil fuels, such as coal and petroleum coke (Marbek Resource Consultants 2008). Over the past 16 years the energy intensity of the Canadian cement manufacturing sector has improved by 11% (CAC 2008, p. 14), but with increased energy prices, economic slowdown, and pressure to reduce greenhouse gas emissions there is an increased urgency to further improve energy efficiency. In 2008 there were fifteen Portland grey cement manufacturing facilities across Canada, and were responsible for 98% of cement manufactured in Canada. Regionally, cement production is concentrated in central Canada, with Ontario (50%) and Quebec (17%) hosting more than two thirds of the industry's installed capacity (CAC 2008, p. 7). Cement manufacturing is a highly energy-intensive process and the fifteen Portland grey cement facilities consumed more than 61,000 TJ of energy in Canada in 2006 (Marbek Resource Consultants 2008). The challenge facing the sector, as with many other industrial sectors, is to not only to identify the opportunities to improve energy efficiency, but also to understand the underlying factors that impede the implementation of the opportunities. To address these challenges the Cement Association of Canada (CAC) commissioned an innovative and comprehensive, integrated energy management benchmarking study.

Energy benchmarking comprises the analysis and reporting of key energy performance metrics to foster continual energy performance improvements in industry through comparison with relevant and achievable internal and external norms and standards. An energy benchmarking analysis generates two important perspectives. First, it provides an overview of how well a particular industry sector or sub-sector is doing in managing energy performance. Second, it enables company participants in a benchmarking exercise to compare the performance of their own plant(s) with the overall industry metrics.

Industrial energy management benchmarking is relatively well established in North America and Natural Resources Canada's Canadian Industry Program for Energy Conservation (CIPEC) has, for example, benchmarked close to twenty industrial sub sectors over the past ten years (NRCan 2009). The earlier benchmarking studies focused exclusively on deriving performance indicators only for energy intensity, i.e. production output per unit energy consumption (NRCan 2009). More recent studies have benchmarked the implementation of best practices, for example the *Best Practice Benchmarking in Energy Efficiency: Canadian Automotive Parts Industry* (NRCan 2005), and one of the first sub sector studies to benchmark both the implementation of best practices and energy intensity was conducted for the Textile industry by Marbek Resource Consultants (NRCan 2006). Marbek has continued to develop the benchmarking approach to integrate the three main elements of energy performance: energy management best practices, technical best practices, and energy use and efficiency. Working with the Cement Association of Canada (CAC), Ecofys and Cement Etc. Inc., the integrated benchmarking approach was further refined by developing an Energy Efficiency Index as the main performance indicator for energy use and efficiency, and by refining the survey instruments developed by Marbek Resource Consultants (CME 2006 and 2007) to obtain data to benchmark the implementation of best practices.

To ensure that the new survey instruments align with existing surveys conducted in the cement industry, the existing surveys and survey data used in the cement industry were reviewed to develop the new survey instruments. The existing surveys and survey data included:

- *Canadian Labour/Environment/Energy (L/E/E) Input* survey developed by the Portland Cement Association.
- *Canadian Environmental R&D Project Questionnaire: Environmental Life Cycle Assessment of Portland Cement Concrete* survey developed by the Portland Cement Association.
- *CO_2 Emissions Inventory Protocol* developed by World Business Council for Sustainability Development (Cement Sustainability Initiative) (WBCSD).
- *Annual Industrial Consumption of Energy* developed by Statistics Canada.

Objectives and Scope

In the context described above, the main objectives of this study were:

- To analyze energy performance and energy management in the Canadian cement manufacturing sector.
- To provide cement manufacturers with tools to make comparisons across time and across peer organizations, in Canada and internationally.

The CAC intends to use energy benchmarking as the first-step in identifying, and quantifying the scale of the potential energy management opportunity available to the industry. The outputs of this project are used to:

- Inform Canadian cement companies' and governments' communications with respect to energy use and energy efficiency in the cement manufacturing sector.

- Inform the on-going development of energy and environmental policies and programs in Canada.
- Support further energy efficiency improvements in the industry.

Specifically, energy benchmarking provides plant owners and managers with insights into issues related to:

- What is my plant's energy performance and energy management profile?
- How do these compare to others in the domestic industry?
- What are the reasons for the differences?
- What opportunities for improvement are available?
- What is the potential economic advantage that might be realized?

The project focused on benchmarking energy performance of Portland Grey cement manufacturing operations in Canada. There were a total of fifteen Portland Grey cement plants in Canada in 2006. All fifteen plants, representing six companies, participated in the study. The study included only on-site processes, while off-site processing and quarrying activities were excluded. The use of all energy sources, such as electricity, fuel oil, and natural gas, by a facility are assessed in the study. The analysis of electricity use is limited to consumption inside the meter and does not include the performance opportunities in upstream electricity generation.

METHODOLOGY

Three survey instruments were developed and used to obtain input from all fifteen Canadian Portland Grey cement plants:

- Management best practices survey.
- Energy technical practices survey.
- Production, energy use and efficiency survey.

Existing surveys and survey data used in the cement industry were reviewed to develop the new survey instruments. The survey instruments were pilot tested at two plants and reviewed by a Steering Committee prior to conducting the survey at all plants. For each site a combination of self-assessment surveys and interviews was used to obtain the data.

The analytical construct to conduct the energy ***management best practices*** (MBP) assessment builds on techniques developed by various organizations internationally. The project team reviewed and analyzed existing energy management models[1], identifying twenty-eight specific Management Best Practice (MBP) areas of relevance to the Canadian cement manufacturing sector. Table 1 provides a short excerpt from the survey instrument to illustrate a sample of survey elements and the structure of the survey instrument. A survey was conducted at each cement manufacturing facility to ascertain the degree to which the identified best practices are currently being employed within the sector. To gain multiple perspectives, three respondents were engaged in the survey for each facility – the plant manager or process engineer, the

[1] The energy management models that contributed significantly to the definition of the competencies are the energy management models developed by Natural Resources Canada – Office of Energy Efficiency, UK Carbon Trust, USA Energy Star, and Australia's EPA Victoria / Sustainable Energy Authority Victoria.

corporate lead on energy issues, and a representative of the corporate executive management team. The MBP score was determined as an average of the three survey results.

Table 1: Example of Survey Elements and Structure of Management Best Practices Survey Instrument

FACILITY ENERGY MANAGEMENT			
Section	**Element**	**Selection**	**Energy Management Elements**
5	**Commitment**		
5.1	**Promotion**	**1**	Energy management is actively promoted at your facility and specific well defined targets to manage and reduce energy use have been developed. Targets and progress are regularly reviewed.
		2	Energy management is promoted at your facility but there are no specific clear targets. Targets that do exist are reviewed on an ad hoc basis.
		3	Energy management is promoted at your facility on an ad hoc basis and does not have specific targets.
		4	Energy management is generally not promoted at your facility.
5.2	**Policy**	**1**	Your facility has a documented energy policy and all facility employees are aware of goals, responsibilities and accountability to implement the policy.
		2	Your facility is developing a documented energy policy, or implicitly follows a policy, with general awareness of goals and responsibilities - accountability to implement the policy may not be well defined.
		3	Some departments implicitly follow an energy policy, but in general there is little awareness of a facility energy policy, and corresponding goals and responsibilities.
		4	There is no facility-level energy policy.

The analytical construct to conduct the ***technical best practices*** (TBP) assessment builds on techniques developed by staff at Lawrence Berkeley Laboratories and other international experts, and the project team. The project team conducted an extensive review of Canadian and international literature to identify technical best practices applicable to the cement manufacturing sector. The review resulted in the identification of thirty-nine Technical Best Practices, which were categorized across the five main cement manufacturing sub-processes:

- Raw materials and fuel preparation;
- Clinker production;
- Finish grinding;
- Cement and feedstock; and,
- General measures.

A survey instrument was developed and completed at each individual facility to assess the applicability of the identified practices and the degree of implementation (i.e. fully, partially or not implemented). Table 2 provides a short example of the survey instrument elements and structure.

Table 2: Example of Survey Elements and Structure of Technical Best Practices Survey Instrument

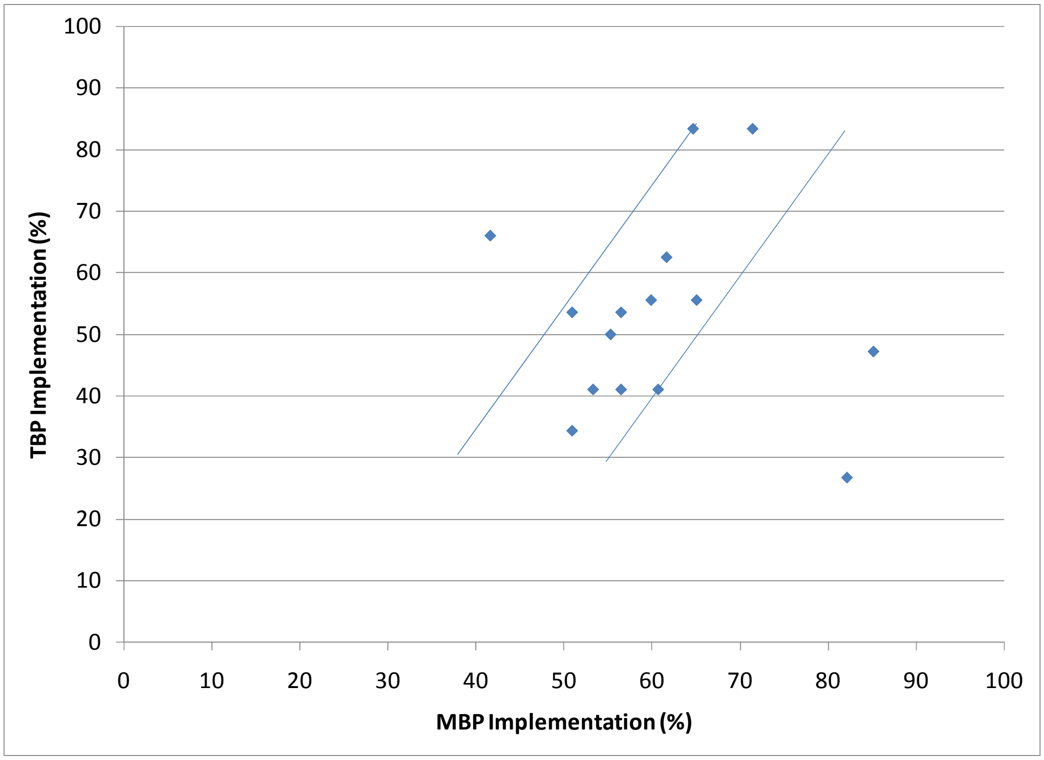
RAW MATERIALS AND FUEL PREPARATION			
Process Step	**Best Practice**	**Best Practice Implemented (No / Partial [i.e. >50%] / Yes)**	**Comments / Description of Best Practice**
Powdered material transport systems	Use mechanical conveyors for powdered material transport.		Pneumatic conveyors are replaced with mechanical conveyors for a savings of approximately 2 kWh/tonne raw material.
Solid fuels preparation	Use a vertical roller mill or ring ball mill for fuel preparation, otherwise for more abrasive coal types, tube mills are preferred.		Vertical roller mill (estimated at 16 - 18 kWh/tonne coal) or ring ball mill replace impact mills (consume 45 – 60 kWh/tonne) and tube mills (consume 25 – 26 kWh/tonne).

An ***energy use and efficiency benchmark*** tool was developed to benchmark energy use and efficiency across plants and process steps. The project team conducted an extensive review of Canadian and international literature to identify potential metrics for measuring overall plant and process-specific energy efficiency. In order to provide capacity for ongoing in-depth analysis concerning energy efficiency in the Canadian cement manufacturing sector, the study team developed an energy efficiency benchmarking tool that evaluates energy performance at both plant and process levels. The tool can calculate various indicators including: total energy intensity (GJ/tonne cement); fuel intensity (GJ/tonne cement / clinker); electricity intensity (kWh/tonne cement); and, an energy efficiency index. The *energy efficiency index* (EEI) allows for more meaningful direct comparison between plants with significant structural differences (e.g. wet kiln vs. dry kiln processes). A theoretical 'best practice' plant was constructed, normalizing as much as possible for structural difference and was given an *Energy Efficient Index* value of 100. Energy use and production data at each manufacturing facility was collected and compared against the theoretical best practices facility.

Selected Results

The results from the surveys were used to calculate the implementation of MBP and TBP, and the energy use and efficiency benchmarking tool was used to determine the EEI. A scatter plot of the MBP and TBP implementation by the fifteen facilities are presented in Figure 1. With the exception of three outliers, the correlation between MBP and TBP implementation shows a general trend where a higher implementation of MBP by a facility is associated with a higher implementation of TBP.

Figure 1: Total Facility MBP Implementation versus TBP Implementation



Besides illuminating the range of total benchmarks for the fifteen facilities, and the correlation between MBP and TBP implementation, the results also highlight the specific areas where best practices have been implemented and were additional opportunities exists. For example, Figure 2 illustrates that most cement companies have focused on energy management practices in financing, communication and commitment, while the energy management areas with the least amount of best practices implementation are: project development, measurement and reporting, and planning. These energy management areas have the largest potential for increased best practice implementation to advance energy management in the Canadian cement industry.

Figure 2: Median Values of MBP Implementation by Category

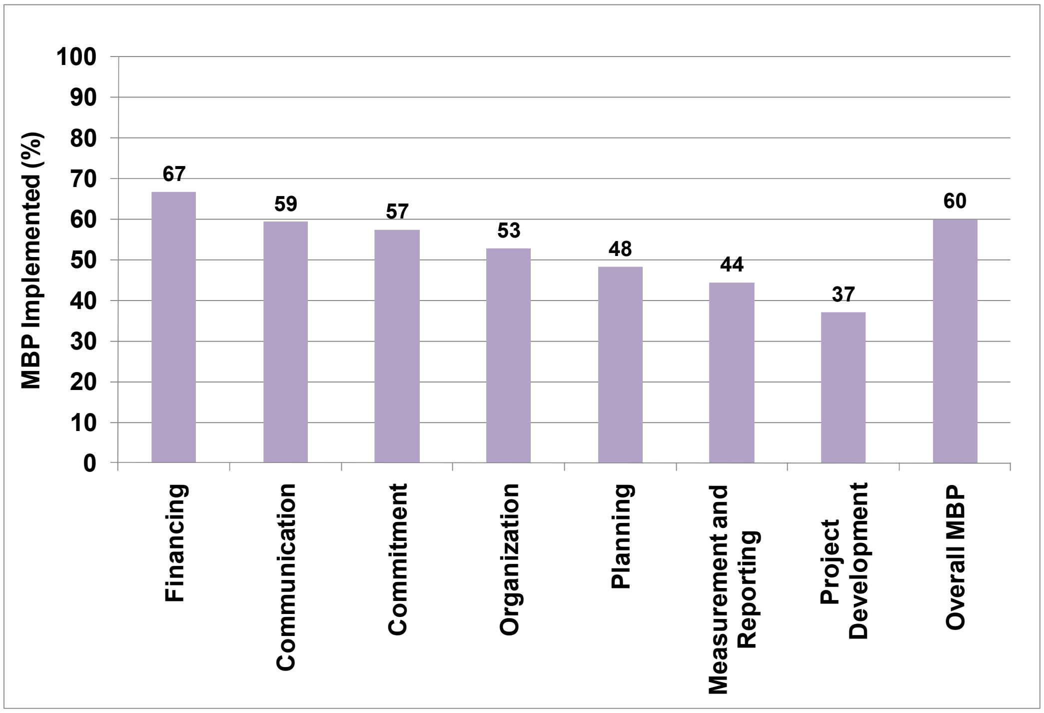


Figure 3 illustrates that the areas where the fewest TBPs have been implemented are in the following process steps: cement and feedstock, and raw materials and fuel preparation. These process steps are also associated with the lowest median EEI, as illustrated in Figure 4. The feedstock and fuel preparation process steps are highlighted as the process steps showing the largest potential to increase the implementation of best practices and improve process-specific energy efficiency. The 2006 energy data collected from the fifteen plants was used to develop an aggregated energy use profile by process step for the Canadian cement industry. This energy profile showed that 90% of the energy is used in the kiln/clinker production process step. This implies that improving the overall EEI depends largely on the energy efficiency of the kiln/clinker production process step.

Figure 3: Median Values of TBP Implementation by Process Step

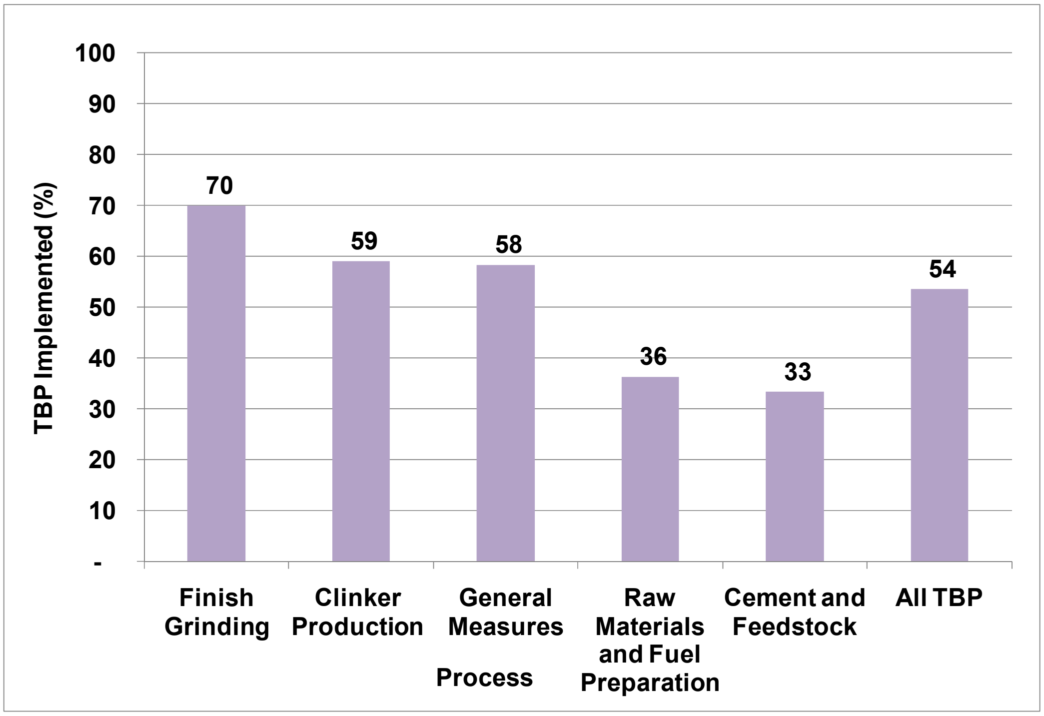


Figure 4: Median Values of EEI by Process Step

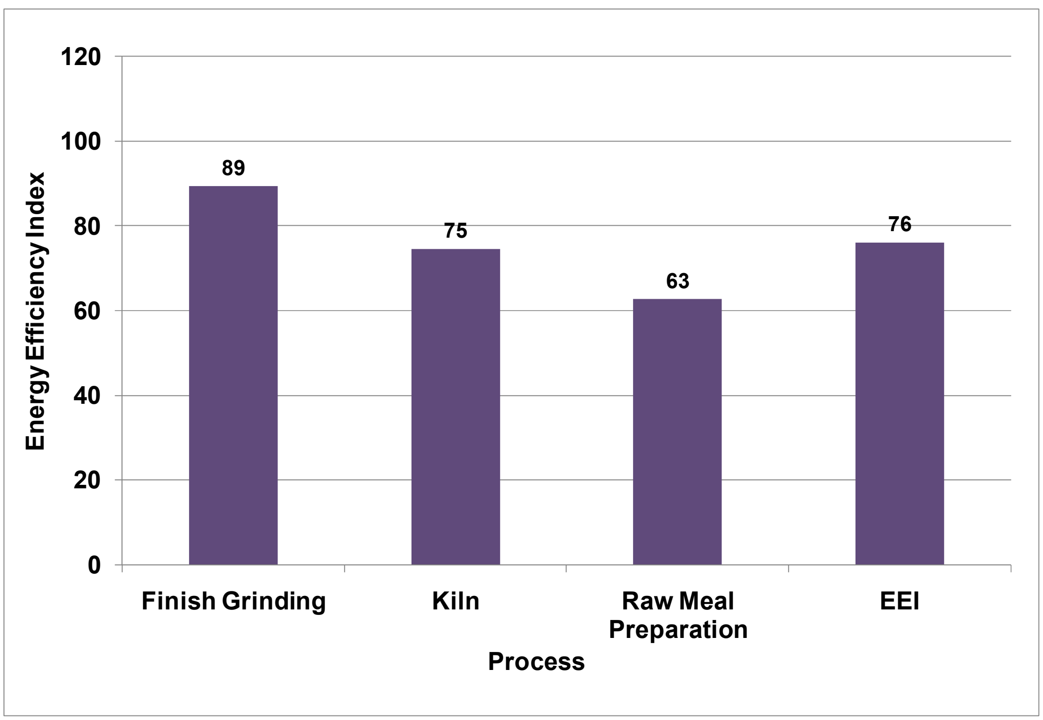
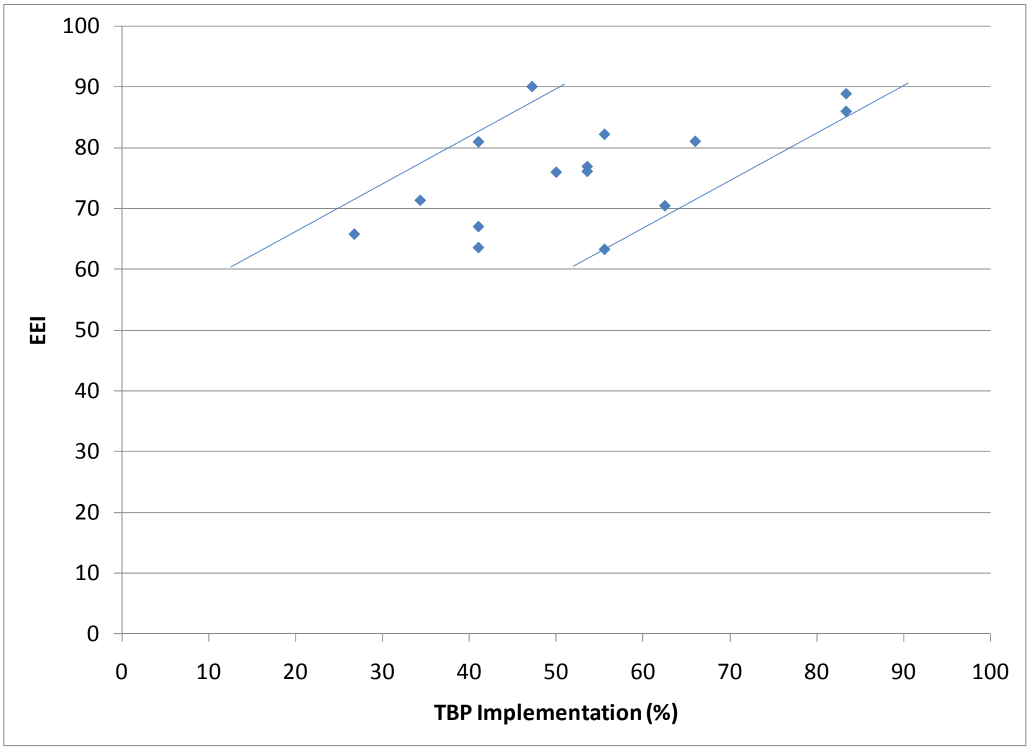


Figure 5: Total Facility TBP Implementation versus EEI



The process step with the highest median TBP implementation is finish grinding, and this is also the process step with the highest median EEI. The results define a clear correlation where an increased implementation of TBPs in a process step is associated with a higher EEI.

The total facility TBP implementation scores are compared with the facilities' total EEI in Figure 5 as a scatter plot. The results show a trend where facilities that have implemented more TBPs tend to have a higher EEI and are more energy efficient.

The benchmarking results can be used to set a goal, or benchmark, for the Canadian cement industry. The EEI results show that more than 50% of the facilities have an EEI above 75, which is generally used as a benchmark for industry. Due to the high efficiency already attained by the cement industry the bar for the cement sector can be raised by selecting an EEI benchmark of, for example, 82. This is the EEI achieved by the top quartile. Implementing the opportunities highlighted by the MBP and TBP benchmarking results will assist individual facilities in achieving the industry EEI benchmark.

Conclusions

Although the Canadian cement sector provides a limited sample of fifteen plants in one industrial sub sector, it clearly illustrates the importance of good energy management practices in managing costs and energy use. Also, it provides evidence of the robustness of the three-pronged integrated energy benchmarking approach. The results for the Canadian cement sector illustrate a relationship between the EEI and TBPs where facilities that have achieved an EEI of more than 85, have implemented at least 45% of the TBPs. Similarly the relationship between TBPs and

MBPs indicates that facilities that have achieved a TBP score of at least 75% generally has to implement at least 60% of the MBPs. It is recommended that the application of the integrated approach in other industrial sectors be researched to further improve the understanding of the relationship between the three elements in industry.

One of the main observations derived from applying the three-pronged integrated benchmarking approach is that energy management practices are key to the successful implementation of energy efficiency as a sustained effort. From a policy and program perspective it would be important for programs to support the implementation of energy management best practices in industry. Furthermore, it shows how benchmarking can be used to define not only performance results, but also to delineate management conclusions. The integrated benchmarking approach is hence a good management tool in itself, which helps to identify the underlying reasons, opportunities and solutions to improve energy efficiency.

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