# Energy Benchmarking & Best Practices in Canadian Textiles Wet Processing[1]

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## ABSTRACT

Under an agreement between the Natural Resources Canada's Office of Energy Efficiency (NRCan OEE) and the Canadian Textiles Institute, a study was commissioned of energy benchmarking and best practices (B&BP) in the 'wet processing' sub-sector of the Canadian textiles industry. The study, completed in 2004, included the survey and assessment of 22 Canadian textile plants in the wet processing sub-sector and culminated in the delivery of 22 confidential plant reports and one industry benchmarking report.

This unique study encompassed three dimensions of benchmarking which were applied to the 22 participating plants: i) an empirical analysis of energy performance; ii) a qualitative assessment of management best practices; and iii) a qualitative assessment of technical best practices.

Two types of reports were prepared from the study: one common industry report with all the industry and per-textile comparisons; and 22 separate plant reports which included further details on plant performance and recommended energy management actions.

This paper will present the results and implications of the study, including a discussion of the unique three-dimensional approach to meeting the benchmarking objectives. The paper presents industry-wide and textile process-specific comparisons between plants using various quantitative energy performance metrics as well as energy management and technical best practices.

The paper also discusses some correlation of the results among the three dimensions of the benchmarking analysis. To illustrate the climate change impact of the industry, the paper also provides the GHG emissions and intensity for the sampled plants.

## Introduction

Energy Performance Benchmarking (EPB) is a tool to inform, motivate and justify cost-effective energy management investment opportunities within industries and individual industry companies that pays off in reduced energy operating costs and improved productivity, thereby enhancing competitiveness. Building on many years of successful partnership with industry, the Industrial Energy Efficiency Program of Natural Resources Canada's (NRCan's) Office of Energy Efficiency (OEE) initiated a benchmarking and best practices program in 2001 for Canada's industrial sector (Office of Energy Efficiency). To date, the OEE has funded 12 benchmarking studies (three completed; nine under way) contributing to the existing inventory of industrial energy benchmark studies conducted internationally.[2]

The Canadian textile industry produces fibres, yarns, fabrics and textile for markets in North America and abroad. In 2003, the industry shipped C$6.5 billion worth of product to

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[1] The Canadian Textiles Institute was a project partner.
[2] Industry Canada.

customers in more than 100 industries, of which about 50% was exported.[3] Like textile industries elsewhere, Canada's textile sector faces intensifying competition as international trade in textiles and clothing is being liberalized, free trade agreements proliferate, and the Canadian dollar strengthens vis-à-vis its U.S. counterpart.[4] Consequently, the control of energy input costs is of ever increasing concern to this industry. Indeed, within the wet processing sub-sector of the industry, it is common for energy costs to represent between 10% and 15% of total operating costs and, in some cases, has been reported to be as much as 50% (*Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005).

At the direction of the Canadian Industry Program for Energy Conservation (CIPEC) and the Canadian Textiles Institute, the study focused on the wet processing sub-sector of the textiles industry. The preparation, dyeing and finishing of textile products consume large amounts of energy, chemicals and water and are referred to in the industry as the wet-processing operations. There are many different wet-processing techniques used in the Canadian industry with particular distinctions in the amount of raw materials required. The wet processing operations were recommended as the focus for the study because they are energy-intensive, reasonably homogeneous in production processes and energy use patterns, and sensitized to the benefits of energy efficiency improvements as a result of the industry's participation in a 2001 Environment Canada study of *Best Available Technology Economically Available* to reduce textile mill effluents. The Canadian wet processing operations produce knit and woven fabric products with the majority of plants located in the provinces of Québec and Ontario.

The study generated two main outputs: i) an industry-wide report for the wet processing sub-sector; and ii) 22 separate confidential plant reports for each of the surveyed companies. The 22 plants represent a considerable portion of wet processing textile output in Canada. In 2003, the 22 participating plants produced 80,500 tonnes (88,736 US tons) of textile output using 2,600 TJ (2,460,000 MMBtu) of total energy, costing them $31.8 million (US$25.4 million) in energy costs and producing 152 kilotonnes (kt) of $CO_2$-equivalent greenhouse gases (GHG).[5] Process energy represents approximately 80% of the total energy use by the plants. Figure 1 shows the wet processing energy end-use breakdown by fuel.

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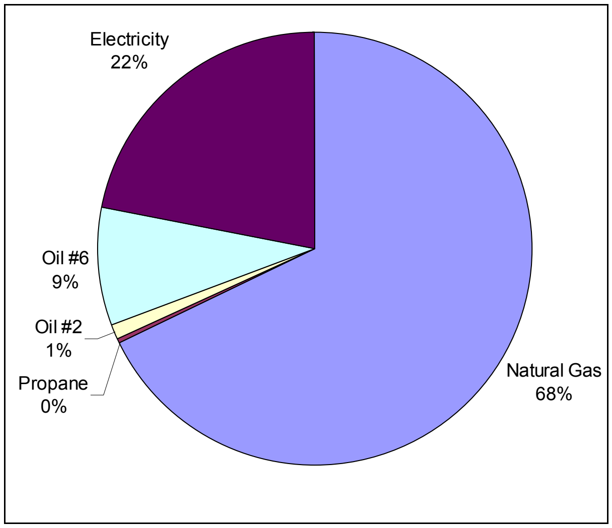
[3] All dollars are 2003 Canadian unless otherwise stated. The foreign currency exchange rate on May 4, 2005 was approximately, C$1 = US$0.80.

[4] Two key drivers are U.S. bilateralism negating some of the benefits achieved under the North American Free Trade Agreement (NAFTA), and the end, in 2004, to the World Trade Organization (WTO) Agreement on Textiles and Clothing (ATC).

[5] 1 tonne = 1.1023113 ton [short, US].

**Figure 1. 2003 Wet Processing Energy End-use Consumption by Fuel for Textile Plants in this Study**




Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report,* February 2005

A considerable body of work had emerged over the years in which energy benchmarking and technical and management best practices studies have been conducted in isolation of each other. This study employed a holistic approach that generated three linked performance metrics: i) an energy use and opportunities profile; ii) a technical best practices assessment; and iii) a management best practices assessment. Together, these three elements of energy benchmarking help to "triangulate" the findings and provide a robust foundation to the results, observations and recommendations. The results confirm the need for a more fundamental approach in this industry that better integrates energy management in corporate policies and day-to-day operations. Advancing technical and management best practices implies taking a long-term view which is a challenge given the hurdles faced today by the Canadian textile industry.

## Setting the Benchmarks

The energy performance benchmark sets a performance target for the participating plants, as well as the industry as a whole, in the textiles industry. Two benchmark values were derived for each of the three performance metrics in the study – a 90$^{th}$ and 75$^{th}$ percentile to identify the top 10% and top 25%, respectively, of plant performance.[6] These benchmarks are less important in absolute terms but are more useful as references against which plants can compare their *relative* performance. While the 75$^{th}$ percentile target is more easily achievable, the 90$^{th}$

[6] The *performance benchmark at the x$^{th}$ percentile* is a calculated value where (100-x)% of samples outperform the benchmark and x% of samples underperform the benchmark. All the samples for a given performance metric are sorted from highest to lowest and the *x$^{th}$ percentile benchmark* is drawn at the position where, numerically, (100-x)% of samples outperform the benchmark and x% underperform. For example, if the 75$^{th}$ percentile benchmark for the Energy Intensity metric is 22 GJ/te (18.9 MMBtu/ US ton), then 25% of plant energy intensities outperformed this benchmark (i.e., had lower energy intensities) and 75% underperformed it (i.e., had higher energy intensities).

percentile may still be within the reach of the textile industry, since there are clearly examples of performance at this level.

## Energy Use & Opportunities Profile

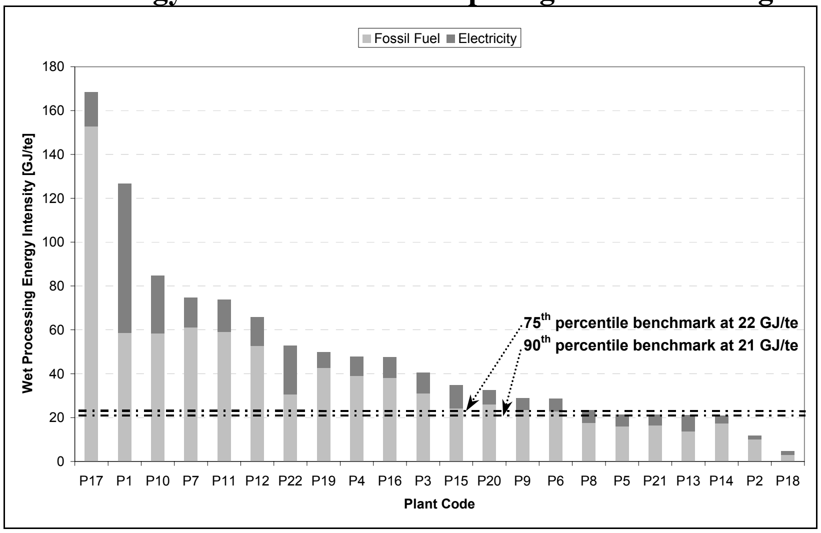
The energy use and opportunities profile is an empirical energy benchmark that shows how efficiently the textile industry is using energy. Energy benchmarking requires comparing energy performance on an "apples-to-apples basis" among the participating plants in a study. However, the wet processing sub-sector is not entirely homogenous in terms of production processes or textile outputs. For example, energy consumption varies from one dyeing-and-finishing plant to another, according to the types of textile being processed; fibre content; fabric weight per unit area; fabric width; construction; types of dyes and finishes being applied; age and size of machinery; and machinery efficiencies. Given this hetro-geneity, the Canadian textiles industry has historically used *terajoules per million dollars GDP* (TJ/$million) as the standard unit in reporting to the Canadian Industry Program for Energy Conservation (CIPEC) for its annual reports.

Notwithstanding previous textile industry practice, we chose to derive the metric as *energy use per unit production output in metric tonnes* (GJ/te), calculated as the sum of all plant energy use for wet processes (converted to GJ), divided by production output in tonnes.[7] This is a preferred energy benchmarking metric is based on *energy use per unit of physical production output*, which better enables a comparison across similar processes and plants (*2001 ACEEE Summer Study*). To standardise the units for production output among plants, all textile measurements of linear metres and square metres were converted by the participating plants to kilograms.

Figure 2 summarises the *energy intensity* among participating plants, resulting in a 90$^{th}$ percentile benchmark of 21 GJ/tonne (18.1 MMBtu/ US ton) of production output and a 75$^{th}$ percentile benchmark of 22 GJ/tonne (18.9 MMBtu/ US ton). The relatively small difference between these benchmarks reflects the small range of plant energy intensities among the top-performing plants. The majority of participating plants underperform the benchmarks, leaving considerable room for improvement in energy intensity among the worst performers. The large range in plant energy intensities (i.e., average energy intensity of 26 GJ/te (22.4 MMBtu/US ton) with a variance of 550%) is suspected to be due to the specific nature of the production processes within each plant and the varying intensities between processing of different textile types.

[7] This derivation of the *energy intensity* metric is consistent with three OEE-funded industrial energy benchmarking studies (e.g., cement, dairy, and petroleum refining studies) and similar foreign studies (e.g., Australian aluminium industry study and UK pig farming and animal feed studies).

**Figure 2. Energy Intensities of Participating Wet Processing Plants**




Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005

## Technical Best Practices Profile

*Technical best practices* refer to production systems and efficiency measures which result in an overall improvement/reduction in energy use per unit of production. The technical best practices encompass equipment, methods or practices that improve energy performance during specific operations. The objective of the technical best practices analysis was to determine the percent of applicable best practices currently being utilised by the textile plant participants.

To set bounds on the analysis, a master list of 48 technical best practices used in the wet processing sub-sector was derived and grouped into six categories of production systems and process machinery:

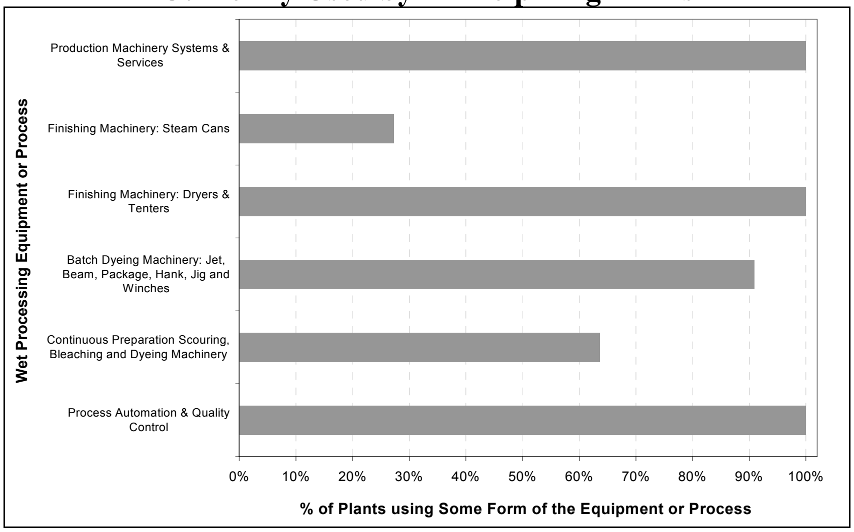
- Process Automation & Quality Control
- Continuous Preparation Scouring, Bleaching and Dyeing Machinery
- Batch Dyeing Machinery: Jet, Beam, Package, Hank, Jig and Winches
- Finishing Machinery: Dryers & Tenters
- Finishing Machinery: Steam Cans
- Production Machinery Systems & Services.

Further analysis was conducted to determine which of the 48 technical best practices were *applicable* to the participating plants. The analysis then determined the extent to which the applicable technical best practices were *implemented* in the participating plants (i.e., fully, partially, or not implemented). The metric generated for the benchmark analysis is a percentage score for each plant equal to the number of technical best practices *implemented* in the plant divided by the number of best practices *applicable* to the plant.[8]

[8] For this calculation, each technical best practice was weighted equally (i.e., no best practice was considered 'more beneficial' to another and thus worthy of a higher weight in the score) and all 'partially implemented' best practices were considered to be 'half-implemented' with an implementation factor of one half.

Figure 3 profiles the wet processing systems and production machinery currently in place among the participating plants. As shown, with the exception of the Steam Can Finishing Machinery, all other production processes/equipment have a high incidence of use.

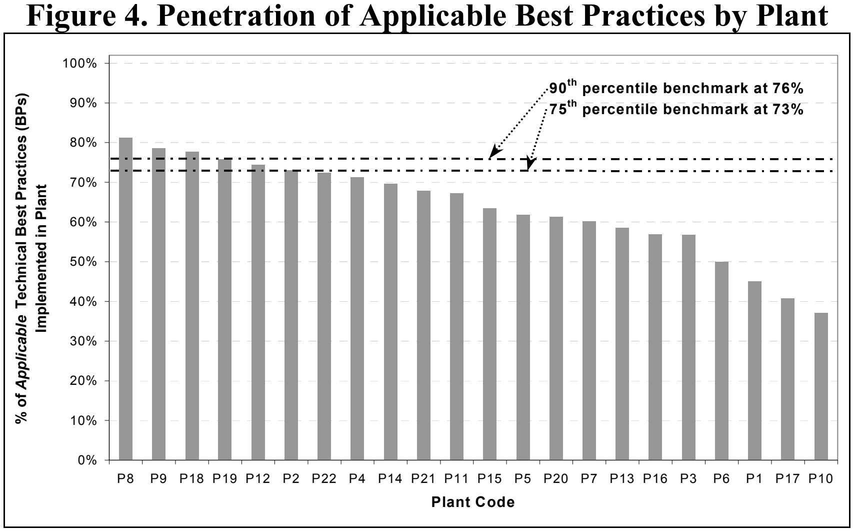
**Figure 3. Wet Process Systems & Production Machinery Currently Used by Participating Plants**




Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005.

Figure 4 shows the percentage of applicable technical best practices currently utilised in participating plants, complete with the industry benchmarks.

**Figure 4. Penetration of Applicable Best Practices by Plant**

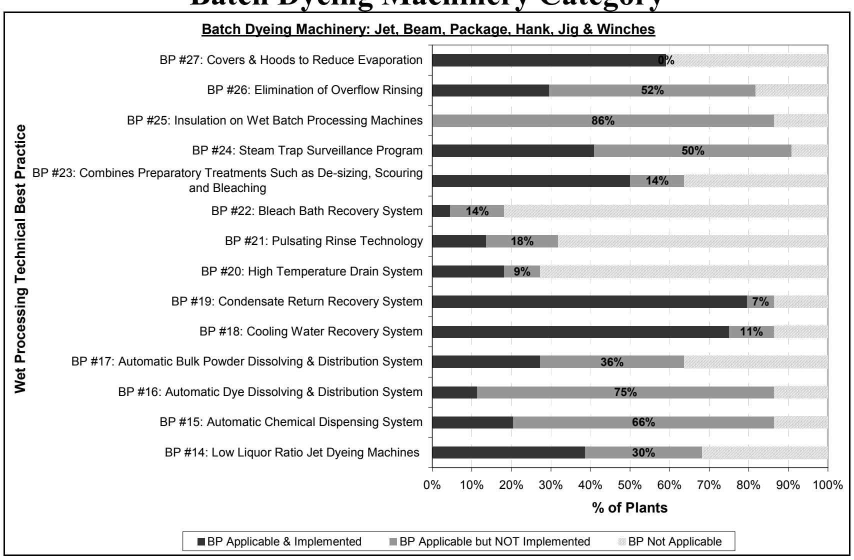



Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005.

As shown in Figures 3 and 4, the 90th percentile benchmark is 76% of *applicable* technical best practices implemented; the 75th percentile benchmark is 73%. Only 3 plants outperform the 90th percentile benchmark, while 5 plants outperform the 75th percentile benchmark. The scores ranged from 38% to 82% with an average of 64%.

The technical best practices assessment further profiles the penetration of applicable best practices (BPs) by category of wet processing system and production machinery. Within each of the wet processing systems and production machinery categories, a profile was derived to indicate the percent of all plants for which the BP is: i) both applicable and implemented; ii) applicable but not implemented; and iii) not applicable. The technical BPs that are applicable but not yet implemented in a large percentage of the plants represent **significant opportunities** for industry investment. For example, nine technical BPs (of the total 48 in this study) are *applicable* but *not yet implemented* in at least 50% of all the participating plants. The technical BPs with the lowest penetration in applicable plants (i.e., the BPs *implemented* in only a small percentage of *applicable* plants) also represent opportunities. For example, seven technical BPs (of the total 48 in this study) are *implemented* in 15% or less of *applicable* participating plants. Figure 5 is an example of this level of analysis for the category of Batch Dyeing Machinery.

**Figure 5. Penetration of Technical Best Practices for Batch Dyeing Machinery Category**

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## Energy Management Best Practices

An *energy management matrix* self-assessment tool was used to assess the energy management in each plant in six thematic categories. To achieve this goal, an analytical construct was adapted from the U.K.'s Action Energy programme (previously known as the Energy Efficiency Best Practice Programme), which developed the original energy management matrix tool.

The energy management matrix self-assessment tool was used to assess management performance against six categories pertinent to energy management:

- **Corporate Energy Policy** – effective management starts with the publication and distribution of a policy statement that commits the organization to energy management as an integral part of its way of doing business by specifying identifiable and measurable targets, which are reported against on a regular basis.

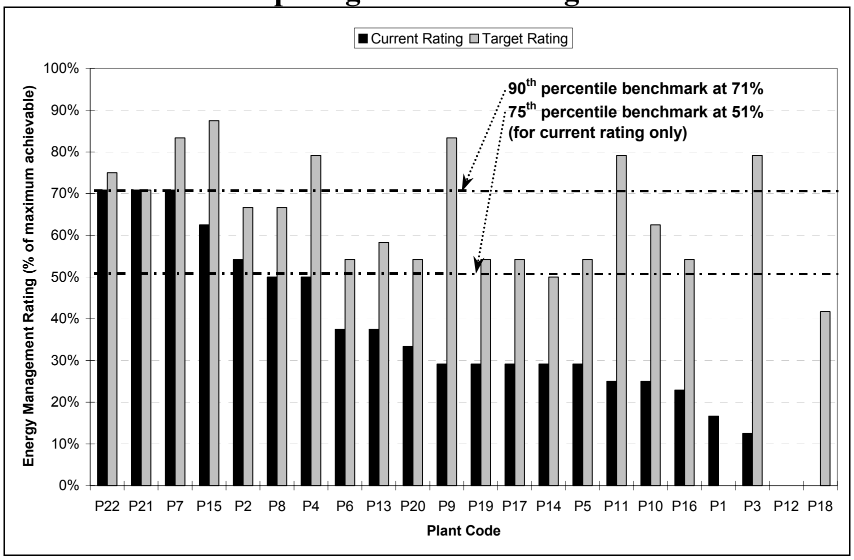
- **Organization** – refers to the organization of people, the allocations of energy management responsibilities, and integration with other management and functions.
- **Skills & Knowledge** – the competencies pertaining to efficient operation, maintenance, promotion and management of energy systems, action plans and equipment. This would include employee training on maintaining equipment and processes that must remain energy efficient to sustain results.
- **Information Systems** – deals with the process of gathering, recording, analysing and reporting data, and putting it to work constructively, in areas such as training, monitoring and measuring management and technical energy performance for the purposes of taking action on identified energy management priorities.
- **Marketing & Communications** – the proactive communication and promotion, both internally and externally, to build and sustain awareness of energy management and its impacts, to receive input from employees on savings opportunities, and to provide feedback on needs and achievements.
- **Planning and Investment** – looking ahead to anticipate future resource requirements, and taking proactive action to investing in energy management measures and technologies, which will benefit the whole organization.

Each of these performance categories was ranked on a scale of 0 to 4, with the higher numbers representing an increasingly sophisticated grasp and commitment to the organizational management of these issues. In general, the levels can be interpreted as follows:

- **Level 0** applies to sites where energy management is virtually non-existent. There is no corporate energy policy, no formal delegation of energy management responsibilities, and there is no programme for promoting energy awareness within the organization.
- **Level 1** generally indicates that, although there is no formal corporate energy policy, some energy management activities are in place, albeit in a rudimentary or informal fashion. Reporting procedures and awareness are undertaken on an ad hoc basis.
- **Level 2** suggests that the importance of energy management is recognized at a senior management level, but there is little active support for energy management activities. Energy staff are likely to be based in a technical department with minimal reporting to management (i.e., energy management is treated as primarily a technical issue and not a management issue). The effectiveness of energy management is restricted to the interests of a limited number of employees.
- **Level 3** indicates that energy management is treated seriously at a senior level, and is incorporated within formal management structures. Consumption is likely to be assigned to cost centre budgets, and there will be an agreed system for reporting energy consumption, promoting energy efficiency and investing in energy efficiency.
- **Level 4** is indicative of clear delegation of responsibility for energy consumption throughout the organization. Energy efficiency is regularly promoted formally and informally. A comprehensive monitoring and system is in place, and performance is closely monitored against targets. Corporate results of energy management are accounted for, reported and reinforced in the annual report.

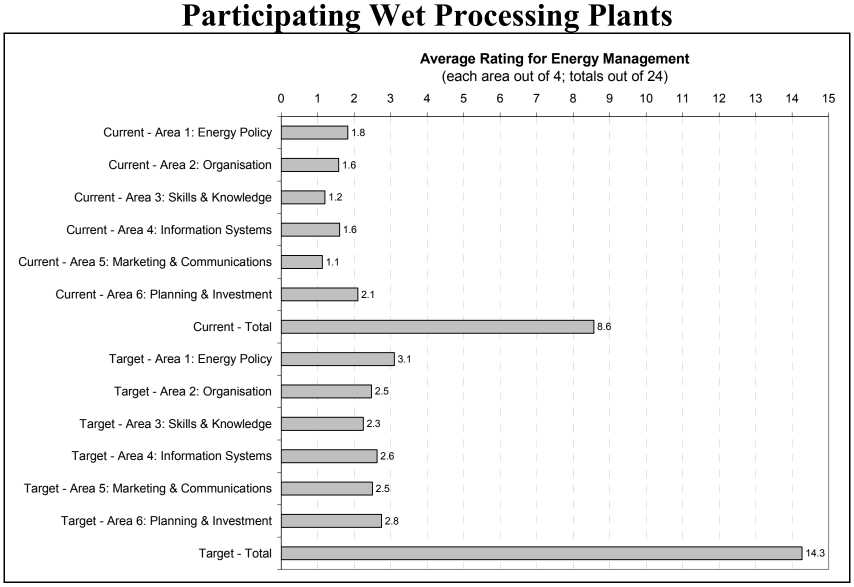
The following management performance indicators are presented for the textiles sector: i) an overall management best practices benchmark; ii) the low and high scores for each management category; iii) the average scores for each management category. Figures 6 and 7 summarise both the current and targeted energy management practices overall, by energy management category. The resulting observations follow.

**Figure 6. Total Energy Management Scores for Participating Wet Processing Plants**




Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005.

**Figure 7. Overall Average Energy Management Ratings for Participating Wet Processing Plants**




Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005.

The *current* energy management practices in Figure 7 show an average rating of 8.6 out of 24, or roughly 35% of the maximum achievable (100%). The 90th percentile benchmark in Figure 6 is shown at 71% of the maximum achievable rating for energy management, while the 75$^{th}$ percentile benchmark is 51%. Three of the 22 participating plants performed roughly equivalent to the 90$^{th}$ percentile benchmark value, while five plants outperformed the 75% percentile benchmark. None of the plants exceeds an overall *current* score of 75%, which is nominally equivalent to a *good* practice rating of 3 out of 4. The results indicate that, as in the case of the other best practice components, there is considerable room for energy performance improvement in the wet processing sector. This appears to be especially the case in terms of translating *good intentions* to actual *good practice* in plant operations.

As shown in Figure 6, almost all of the participating plants have *targeted* improvements in their management practices. However, only six of the participants indicated an overall *target* score above 75%. There is evidently a need for greater orientation among the plants of what can be realistically attained to bring operations to a higher level of *good* practice. Overall, the *target* energy management practices in Figure 7 show an average overall target rating of 14.3 out of 24, or roughly 60% of the maximum achievable.

Focusing on the six energy management categories in Figure 7, the average *target* rating for each category reveals that Energy Policy scored the highest at 3.1 out of 4 or roughly 75% of maximum achievable. The lowest scored category for *target* rating was Skills & Knowledge with 2.3 out of 4, or roughly 60% of maximum achievable. Energy & Policy and Marketing & Communications were the two areas of energy management with the largest jump from average *current* to *target* ratings, with roughly 70% and 125% target improvement, respectively.

In Energy Management, specifically, the priority for action would be to raise the lowest scores with a long-term objective to improve in all energy management categories towards a balanced profile (consistent 3's and 4's across all categories).

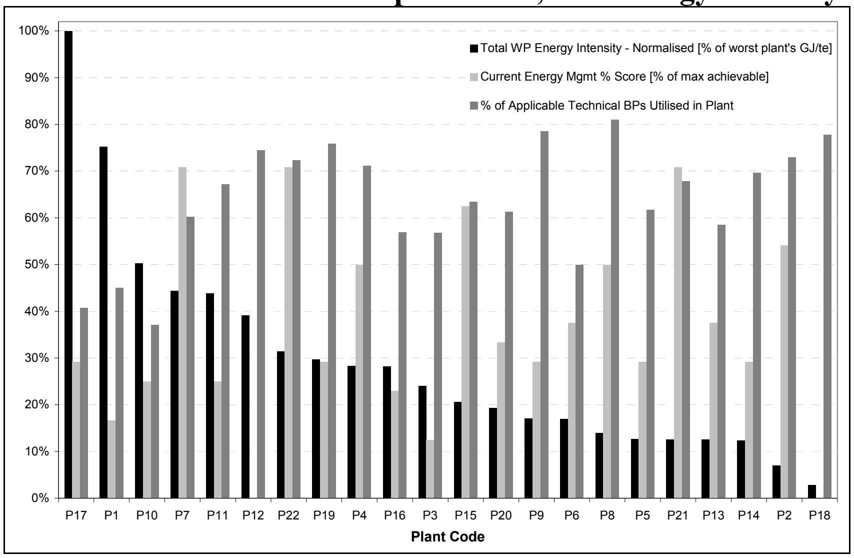
## Possible Correlations Among The Three Benchmark Components

The results of all three benchmark analyses indicate that the participating plants have an opportunity to improve energy performance and reduce operating costs through the application of both management and technical best practices. However, these observations are the result of three discrete analyses. Further analysis was conducted to investigate possible correlations among the three benchmark components.

Figure 8 presents the results of the correlation analysis and shows a *clear correlation between technical best practices and energy use intensity*. This observation is confirmed by the statistical correlation coefficient (r) of 0.64.[9] The plants with the highest energy intensities have implemented the lowest percentage of applicable technical best practices and, conversely, those plants with the lowest energy intensities have implemented the highest percentage of applicable technical best practices. There is a more *subtle correlation between management best practices and energy use intensity,* which is also confirmed by their correlation coefficient of 0.27. Correlation between technical best practices and energy management practices was not analysed.

[9] Correlation Coefficient, denoted as "r", is the measure of the linear relationship between two variables. The absolute value of "r" provides an indication of the strength of the relationship. The absolute value of "r" varies between 0 and 1, with 1 indicating a perfect linear relationship and 0 (zero) indicating no relationship.

**Figure 8. Correlation between Energy Management, Technical Best Practices Implemented, and Energy Intensity**




Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005.

## Challenges & Opportunities

The study reveals that there continues to be a large potential for energy efficiency improvements across all of the major process components of the wet processing sub-sector. The results show a significant variance in performance for each of the three performance metrics, illustrating a significant number of plants with large potential for improvement.

The challenge of controlling energy use and costs is not insurmountable. Improvements are attainable and the plant site assessments reveal opportunities that can be pursued in three interrelated areas, discussed below.

### Opportunity 1: Integration of Energy Management in the Corporate Mandate and Structure

- Improving the practice of Energy Management, both in improving current practice and in demonstrating the benefits of establishing aggressive target levels. This could be done by demonstrating the link between Energy Management practice and energy performance as demonstrated in the Correlation above.
- Focusing on incremental improvement of the Energy Management areas of Skills & Knowledge and Marketing & Communications.
- Improving targeting and monitoring. None of the participating plants monitored energy usage on a production process or end-use basis. As a result, it is difficult for plants to know, without detailed analysis, the energy usage and contributions of processes to the overall energy picture at any point in history and in particular according to current operations. To enable effective management of energy use and greenhouse gas emissions, monitoring and targeting is an essential tool – "you can't manage what you don't measure."

**Opportunity 2: Introduction and Promotion of Technical Best Practices**

- Promotion and assessment of technical best practices that have been identified as applicable to a large percentage of plants in the textiles wet processing sub-sector, but which have had relatively low levels of implementation (less than 50% implementation) as a whole.
- Promotion and assessment of technical best practices that have had a low level of implementation (less than 15% implementation) in relation to their overall applicability.
- Consideration of the concept of integrating energy conservation measures into the process of capital turnover to introduce new process modification and components to help reduce lost opportunities.

**Opportunity 3: Implementation of Capital and Low/No-Cost Measures**

Based on the on-site observations collected and assessed at each of the 22 participating plants, a number of technical best practice opportunities were identified that present a consistent financial benefit to participants. The costs and savings potentials of those measures are summarized below in Table 1.

**Table 1. Financial Returns of Key Best Practice Measures among Participating Wet Processing Plants**

| Measure | Cost* | Savings* | Average Simple Payback |
|---|---|---|---|
| **A: Process Automation & Quality Control** | | | |
| BP#1: Dyehouse Host Computer Control System | M | L | 4.3 |
| BP#2: Automatic Microprocessor Dyeing Machine Controllers | M | M | 0.9 |
| BP#5: Automatic Dye Laboratory Color Mixing | M | L | 2.5 |
| **B: Continuous Preparation Scouring, Bleaching and Dyeing Machinery** | | | |
| BP#13: Point-of-Use Heat Recovery System | M | L | 1.8 |
| **C: Batch Dyeing Machinery: Jet, Beam, Package, Hank, Jig and Winches** | | | |
| BP#15: Automatic Chemical Dispensing System | H | L-H | 2.9 |
| BP#16: Automatic Dye Dissolving and Distribution | H | M | 4.4 |
| BP#17: Automatic Bulk Powder Dissolving & Distribution | H | M | 4.6 |
| BP#18: Cooling Water Recovery System | M | L | 3.6 |
| BP#19: Condensate Return Recovery System | L | L | 4.3 |
| BP#24: Steam Trap Surveillance Program | L | L | 1.9 |
| **D: Finishing Machinery: Dryers & Tenters** | | | |
| BP#29a: Moisture Humidity Controller | M | L-M | 2.4 |
| BP#29b:Dwell Time Controls System | H | L-M | 4.7 |
| **E: Finishing Machinery: Steam Cans** | | | |
| — | — | — | — |
| **F: Production Machinery Systems & Services** | | | |
| BP#40: Wastewater Heat Recovery System | M | M | 1.9 |
| BP#41: Boiler Stack Exhaust Recovery System | H | L-M | 2.9 |
| BP#42: Boiler Room De-aerator | M | M | 3.5 |
| BP#43: Air Compressor Cooling Water Recovery System | L | L | 2.4 |
| BP#45: Water Minimization Program | M | M | 4.7 |
| BP#46: Preventive Maintenance Program | L | L | 2.9 |
| BP#48: Direct Gas Fired Air Make-up Units | M | M | 2.0 |

* Low = $0 - $50,000; Medium = $50,000 - $250,000; High = More than $250,000

Source: *Energy Performance Benchmarking and Best Practices in the Wet Processing Sub Sector of the Canadian Textile Industry-Draft Report*, February 2005.

In general, the opportunities ranged in implementation cost from low (less than $50,000) to capital intensive (in excess of $250,000). These measures represent the best opportunities from a cost effectiveness perspective in the textile wet process sub-sector represented by the sample in this study. Despite the cost and savings ranges of this list, it must be pointed out that on-site conditions at any specific plant would determine the cost and savings implications of implementing any of these measures. The individual plant reports identify the specific recommendations and financial assessment of the related applicable measures. This list represents cost effective best practices that consistently delivered savings in excess of the initial capital outlay within a five-year period and on average within four years, overall. These measures could be supported and implemented in the sub-sector.

Some plants were found to be already well engaged in the application of ambitious energy management programs. In other cases, very little has been done. Regardless, there appears to be considerable room for improvement on an industry wide basis. The target benchmarks employed in the analysis should not be considered as the final destination for performance improvements; they fall short of the optimum that can be achieved.

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