“Benchmarking: business strategy to improve environmental performance”

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Benchmarking: business strategy to improve environmental performance

Abstract

A growing number of organizations have failed to realize that environmental strategies should be incorporated as part of the organizations corporate business strategies, to ensure their sustainable competitive advantage. Future sustainability and competitiveness require the adoption of Cleaner Production (CP) techniques and technologies which will address waste issues at its source and ensure more efficient use of resources. However, management is not keen on this strategy as they perceive CP as a costly strategy that requires innovation with no financial benefits to the company. The aim of this paper is to benchmark the company's environmental costs by comparing the company's current non-product output against technological standards and standards of best available technology. The results are based on a case study which is focused on the coal – fired boiler technology used in the steam generation process. It had been found that benchmarking enabled managers to evaluate and analyze how much they can save by ensuring that their current technology is functioning according to technological standards and also reduces the amount of waste generated due to technological inefficiency.

Keywords: environmental strategies, benchmarks, non-product output, best available technology, Cleaner Production techniques, technological standards, competiveness, sustainability.
JEL Classification: O32.

Introduction

In many developing countries strategies to reduce dependence and use of energy from fossil fuels need to be introduced, due to an increase in industrial activity (Stringer, 2010).

Profitability and competiveness are affected by inefficient production processes. Most companies are using outdated technologies. This, ultimately, results in higher production costs which, in turn, affects their profitability and competitiveness. The direct consequences of these inefficiencies are rapid environmental degeneration, excessive amounts of pollution and waste generation which, in turn, is hazardous to human health and affects quality of life (Schaltegger et al., 2010; Despeisse, Oales and Ball, 2013). Cleaner Production strategy is still very appropriate for companies in both developed and developing countries (Berkel, 2011).

Companies are using conventional costing systems which do not provide managers with information regarding the value of their non-product output costs. Therefore, senior managers view environmental costs as being insignificant and investment in CP technologies is not considered. Audits into Cleaner Production assessments of production centres found that there are large savings potential and opportunities to be enjoyed but companies are not aware of it since there is no monitoring and data collection in place. As the old saying goes, 'what you do not measure you cannot manage'. The environmental and sustainability accounting tool, Environmental Management Accounting (EMA) gives companies the opportunity to collect, evaluate and interpret the information needed to estimate their potential for Cleaner Production saving and to make decisions to choose the right CP options (Schaltegger et al., 2010).

Companies implementing EMA systems needed to know exactly what they had to gain by using it and its role in CP. This was facilitated by making use of material flow analysis, a tool of EMA (Jasch, 2009). The Cleaner Production Assessment (CPA) is an important step that organizations need to make to identify inefficiencies in a production process and benchmark environmental costs to yield superior environmental and economic performance. Private environmental costs lead to higher prices and reduced competitiveness (Pons, Bikflavi, Llach and Palcic, 2013).

Significance of the study. Although most companies are ISO14001 certified due to strict environmental regulations and market pressures, CP implementation remains slow and lagging. Many have adopted end-of-pipe technology as part of their sustainable practices. Waste disposal to landfill sites is steadily increasing. In order for a company to remain sustainable and to achieve eco-efficiency in their production processes, there is an urgent need to adopt Cleaner Production techniques and technologies as part of the strategy towards sustainable development (Despeisse et al., 2013). As part of the requirement of ISO14001, it is critical that companies look at ways to achieve sustainable competitive advantage by improving their production process by implementing the use of cleaner technologies that reduce their raw material input thereby resulting in lower amounts of waste or

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at times no waste at all. This will, ultimately, result in improved environmental performance and increased economic performance (Radonjic and Tominc, 2007).

Short-term profitability is being prioritized at the expense of the environment. Organizations need to find ways to ensure their long-term sustainability. Accountants and financial managers need to be made aware of the costs associated with unsustainable production processes, that is, '*environmental costs*' (Environmental Sustainability Performance (ESP) Benchmarking, 2013).

Managers are more focused on cost-reduction options using existing technology. Cleaner technologies are more efficient as they prevent emissions at source. These approaches are costly and inefficient (Jasch, 2009). However, relatively newer technologies are unlikely to be replaced by cleaner technologies even if they can result in improved environmental and economic performance. Therefore, when benchmarking environmental costs, life-cycle of existing technology must be considered. In the short-term, good housekeeping measures or minor improvements are preferred as part of Cleaner Production strategy.

In the medium-term, it makes sense that a company may change technology and get closer to state-of-the-art of the industry. It is only in the long-term that companies will consider changing state-of-the-art to get closer to the ideal world of zero emissions where all inputs become part of the product. Theoretical standards are used to reflect this ideal world with no waste (Schaltegger and Csutara, 2012).

At the conclusion of this study, managers will be able to evaluate and analyze how they can improve both their environmental and economic performance in the future and attain their sustainability targets by implementing the benchmarking strategy.

1. Literature review

An expert in competitive strategy at the Harvard Business School, Michael Porter, observed that "like defects, pollution often reveals flaws in the product design or production process. Efforts to eliminate pollution can, therefore, follow the same principles widely used in quality programs: use inputs more efficiently, eliminate the need for hazardous, hard-to-handle materials and eliminate unneeded activities". Recent studies documented the economic benefits of using resources more efficiently and also reported that firms that invested in ECF and TCF bleaching technologies showed better economic performance (Bras et al., 2004).

However, changing from pollution-control to pollution-prevention technologies takes time, money, and a holistic approach to managing the environmental issues associated with pulp and paper manufacturing. Pollution-prevention technology investments can be costly and often compete for capital funds together with other projects that would also improve the company's profitability. In order to remain competitive, mills will have to respond with new technologies and if this decision results in the firm incurring high costs, these costs are most likely to be passed on to purchasers. Therefore, paper companies must consider how much capital needs to be invested in order to reduce operating costs. This has been the trend for the past 20 years.

Capital-allocation decisions of paper manufacturers are dependent on the following factors:

- The company philosophy toward environmental performance. Integrating short- and long-term goals along with cost, productivity and quality in every investment decision.
- Investing additional capital to reduce operating costs that provide economic benefits to the mill.
- Mills need to replace old, obsolete technology to ensure sustainability.
- Site-specific costs increase capital costs to install pollution-prevention technologies.
- Capital investment decision also depends on shifts in customer demand and new environmental regulation.

Timing and range of capital costs to install pollution-prevention technologies differ for individual mills:

- The decision to add a paper machine will depend on how much more pulp than paper is produced by the mill.
- Mills that have average to low capital costs to install pollution-prevention technologies will do so to take advantage of lower operating costs.
- Mills with higher capital costs will wait until the combination of factors improves economics of the investment.

Recent survey of recovery boilers found that over 70% were more than 25 years old and will, therefore, have to be rebuilt or replaced in the next decade. Minor renovations, replacement of individual pieces of equipment and the elimination of bottlenecks will have to proceed at a greater rate than major renovations or expansions. It can be concluded that integrating pollution-prevention strategies into pulp and paper manufacturing need to be part of the capital planning process that integrates a long-term vision for environmental progress with improvements in quality, productivity and lower operating costs.

Empirical evidence/studies found that environmental regulation and investments in pollution abatement technologies did have a 'depressing effect' on growth. This is contradictory and does not consider potential positive effect associated with compliance with environmental regulations or that improvements in technologies enhance production efficiencies that resulted in growth levels that were more than twice than that attained through traditional productivity analysis methods. Bras et al. (2004) suggest that capital expenditures on pollution abatement result in a loss of productive capital. The general view is that 'every penny spent complying with green rules means a penny less spent on building more mills'. Porters' hypothesis of the 'win-win' scenario states that if environmental regulation was properly designed, it could inspire innovation that will allow companies to use their inputs more productively to offset the costs of improving environmental impact. Empirical studies conducted on paper and pulp industry found that paper industry input use and pollution could be reduced from between 2 to 8% without adverse effects on productive output. Porter suggested that a strategy aimed at enhanced resource productivity will make companies more competitive. The two impediments that were identified to using environmental issues to gain competitive advantage were: ignorance about direct and indirect environmental impact; and limitations of conventional accounting systems for tracking environmental costs.

During an investigation by Stringer (2010:xiv-3) into Cleaner Production measures for improving the water system and sludge utilization efficiency in the mill in Serbia, recommendations were made to adjust in-mill and end-of-pipe measures. In-mill measures were closure of internal water system to reduce water consumption and sludge reuse in production. End-of-pipe measures included upgrading of effluent treatment plant (ETP) to improve efficiency and quality for in-mill reuse. It had been concluded that the Cleaner Production measures for in-mill water system closure and end-of-pipe measures would result in savings in the first year. The estimated cost of the investment to adopt the Cleaner Production measures was 865000 Euros. Considering the higher water prices in Serbia as compared to prices in other European countries, a payback period of 7 years was calculated. Hence, environmental and economic benefits were identified by adopting Cleaner Production improvement measures.

Investing in technologies to improve the company's ability to identify and quantify 'win-win' capital investment and operational improvement opportunities through improved access to and analysis of production and environmental accounting information can support decisions of a corporate commitment to profitability and sustainability.

A study was conducted by Henriques and Sadorsky (2007, pp. 119-132) in the Canadian manufacturing industry to determine the factors affecting a facilities decision to implement, cleaner technological innovations by drawing on stakeholder influence and Drafts (1978) dual core model of organizational innovation.

It was discovered that external stakeholders, such as regulators, community and environmental groups, have a greater impact on technological innovations and increase the likelihood that facilities will use cleaner technologies as compared to corporate headquarters and shareholders investors who have no impact on technological innovations. However, contradictory arguments have also been reported that EMA involves complex analysis, such as material balances, to track and gather information on environmental costs which is expensive and may not always be cost effective (Abdel-Kader, 2011, p. 67).

Research to develop a greater understanding of Cleaner Productions from a technology management perspective within the SA automotive industry with a focus on improvement techniques discovered that development of cleaner technologies is slower in developing countries such as South Africa, due to greater emphasis being placed on economic growth rather than environmental protection. The results highlighted that technological improvements can be achieved through CP, however, they were mainly through incremental innovations in secondary process. These incremental innovations involve adoption, refinement, and enhancement of existing products and services and/or production systems whereas radical innovation which involves extremely new products or production system occurs at after lesser extent (Pandey and Brent 2008, pp. 171-182).

A study conducted by Christmann (1999, p. 12) to investigate the 'effects of "Best Practices" of Environmental Management on cost advantage', which focused on the role of complementary assets. His findings concluded that complementary assets must be specific to the firm and also not be easily transferable to, or imitable by, other firms, in order to create competitive advantage. The relationship between Environmental Management and competitive advantage of a firm and the role of complementary assets on this relationship had not been empirically explored. Christmann (1999, p. 13) also posed an argument that it may not necessarily be true that environmental performance will have a positive impact on competitiveness of a firm. He suggested that competitive advantage in product markets and the higher financial performance may encourage firms to adopt environmentally responsible strategies. Empirical literature on the effects of the three best practices identified by Christmann (1999, pp. 14-16) and their impact on cost advantage suggest the following hypotheses:

H1: The higher a firm's use of pollution-prevention technologies, the larger will be it cost advantage from environmental strategies; H2: The higher a firm's level of innovation of proprietary pollution-prevention technologies, the larger will be its cost advantage from environmental strategies; H3: The earlier a firm's timing of environmental strategies, the larger will be its cost advantage from environmental strategies.

1.1. "Best Practices" of environmental management. Christmann (1999, pp. 13-17) analyzed three process-focused "Best Practices" of Environmental Management during his research to identify their direct effect on cost advantage:

- Best Practice 1: Use of pollution-prevention technologies. Pollution-prevention technology has the potential to increase the efficiency of the production through reduced input costs, substitution of less costly inputs, savings from recycling or reusing materials, and reduction of waste disposal costs.
- Best Practice 2: Innovations of proprietary pollution-prevention technologies. Internal innovations of pollution-prevention technologies contribute to the firm's cost advantage in many ways: first, managers become aware of inefficiencies in current production processes and products that were not previously recognized, by developing new pollution-prevention technologies. Second, innovations of pollution-prevention technologies have greater potential for cost-saving changes in the production process. Third, the technologies are proprietary to the firm, therefore, the firms are likely to appropriate the rents that are created by these internally developed technologies. Competitors are not easily able to imitate these internally developed pollution-prevention technologies.
- Best Practice 3: Early timing. Addressing environmental issues earlier than competitors or before environmental regulation is established contributes positively to cost advantage by minimizing disruptions of the production process usually caused by the implementing compliance technologies, allowing the firm to gain cost advantage through the learning curve effects, by addressing environmental problems early and influencing regulations can raise their competitors costs.

A study by Jonall (2008, pp. 23-27) which involved the development of a microeconomic model where clean and dirty technologies compete in production and innovation. Their findings were that the optimal policy relies heavily and research subsides. Theoretical carbon taxes and research subsidies were found to encourage production and innovation in cleaner technologies. An organization must have capabilities for process innovation and implementation to improve the efficiency of a production process and also gain cost advantage from implementing and innovating pollution-prevention technologies (Christmann, 1999, p. 18).

Jonall (2008, pp. 23-27) discussed some of the Environmental Management Accounting depending factors during her review of articles previously published. Some of the issues analyzed and discussed if external pressures were a driving force for environmental activity in companies; the role of accountants in providing quality information, for example, categorizing costs as cost of waste and non-renewable resource use instead of letting them be reflected as general overheads or fixed costs, to support decision making in Environmental Management issues and making stakeholders aware of the importance of sustainability as a business strategy; exchange of information and knowledge within the organization to ensure that the environmental manager has access to the actual Cost Accounting documents to know true environmental costs; information systems for Financial and Cost Accounting and process technicians should be on common consistently following the material flows through the company; and intangible assets indicating environmental embeddedness at 3 levels: level 1, primary, Environmental Management Systems (EMS) to ensure continuous environmental performance improvement, level 2, visible, influence of environmental issues on organizational structures and strategies, level 3, advanced, use of Management Accounting cost systems, capital budgeting, scorecards and other advanced Management Accounting practices.

1.1.1. Role of Environmental Management Accounting (EMA) in Cleaner Production implementation. In order to achieve sustainable competitive advantage, businesses need to adopt CP processes (Fore and Mbohwu, 2010; Pons et al., 2013).

A test project undertaken by Schaltegger et al. (2010) to assess the sustainable performance of companies after a combined application of EMA, CPA and Environmental Management system (EMS) generated positive outcomes by increasing awareness of the economic implications of the environmental impact of non-product output and costs, and provided a systematic method of controlling these costs in the short-, medium- and long-terms. EMA also helped to quantify monetary benefits of adopting alternative CP options (V'an, 2012).

EMA and the balance scorecard were introduced to industry as a means to measure sustainability factors to compare and benchmark environmental performance (Lambert, Carter and Burritt, 2012).

2. MFCA and non-product output costs

The most significant share of total environmental costs is usually non-product output costs. An EMA system can provide information needed that could be used for directing decisions towards the adoption of Cleaner Production measures implementing new technologies to reduce these costs (Domil, Peres, and Peres, 2010).

Hyrslova (2011) believes that an EMA system provides users with valuable information regarding the material purchase value of non-product output and makes it possible to track and trace where non-product outputs are created. Management can use this information to propose measures to increase the efficiency of material use that will reduce environmental impacts and, concurrently, improve economic performance of the organization.

The purpose of material flow balance as explained by Jasch (2009, p. 832) is to completely understand how much of what is put into the system becomes a product, and how much becomes non-product output (NPO). He suggests that understanding NPO is the best way to manage environmental issues. The generation of waste or NPO is a sign of inefficient production. Therefore, material flows are not only important for assessment of environmental cost, but also for production oriented cost assessment. It had been concluded that Material Flow Cost Accounting (MFCA), although in its imperfect form, is a powerful tool to ensure the future sustainability of a business. Schmidt and Nakajima (2013) concluded that a key concept of MFCA is to distinguish between product cost and non-product output, to evaluate which streams of material ends up as part of the final product and which streams of material are non-product output. One of the major cost drivers reported during company workshop studies was the material purchase value of non-product output (Jonall 2008, p. 32). Thus, evidence has been found that has identified material purchase value of non-product output as the category of EMA that has the potential of largest cost savings as stated by Jonall (2008, p. 40).

Non-product outputs are a major cost factor for companies considering that polluting companies actually pay three times for non-product output. First, the cost of purchasing the raw material which ends up as wasted material. Secondly, the company incurs costs for operational use of raw material, for example, labor and investment cost. Finally, the company then pays for the disposal of this wasted material (Jonall, 2008, p. 42).

This is the actual cost of the wasted material which most companies fail to realize. Making them aware of this can create the need to improve material efficiency by investing in newer Cleaner Production technologies. Not all wastes and emissions can be eliminated even if state-of-the-art technology (BAT) technology is used. Domil, Peres, and Peres (2010) believe that a more suitable approach to help managers plan Cleaner Production measures and investments in cleaner technologies, would be to create three different benchmarks against which companies can compare their non-product output costs. These benchmarks will be an indication as to how a company can manage and control their non-product output costs in the short-, medium, and long-terms. The first standards indicate technological norms. These represent the most efficient use of material at optimal functioning of the company's existing technology. This standard allows for waste and emissions that cannot be avoided by operating existing technology in an efficient way. These standards can be accessed from technical manuals and process flow chart analysis. Actual costs of inputs are compared to inputs if technological norms were followed, this difference is quantified and evaluated to establish how much a company can save in the short-term if the existing technology was operated efficiently.

Best available technology (BAT) levels are more stringent. These technologies are considered the most efficient and environmentally protective available on the international market currently. These standards can only be achieved in the medium-term when the company can switch to BAT or significantly modify its existing technology. Savings that could be possible by switching to BAT are evaluated by the difference between actual costs of inputs and inputs for BAT norms. This benchmark reflects some waste and pollution will be generated but lower quantities than technological norms. This is generally the benchmark used in calculating non-product output cost in most literature. The final benchmark is the theoretical norms. This standard reflects a 100% efficiency, which requires significant technological development and is only achievable in the long-term (Schaltegger et al., 2010).

Therefore, much larger potential lies in reducing the costs of materials, but it is this potential that is left untouched by traditional environmental costing.

There is a need to increase awareness of the benefits of this new tool to organizations that generate lots of waste during their production processes. Companies can use their previous financial data and apply the MFCA approach to identify the monetary and physical values of their losses in the form of non-product output costs.

This will help them to identify saving opportunities by investing in CP technologies that use less input resources and generate less waste, improving both environmental and economic performance (Lagioia, Tresca, and Gallucci, 2014).

Non-product output costs can represent between 10-30% of total production costs of a company (Arlinghaus and Berger, 2002). Making managers aware of this can create the need to improve material efficiency by investing in newer Cleaner Production technologies.

Domil, Peres, and Peres (2010) discuss the different levels of non-product output costs and how they can be controlled within different time frames. The difference between actual non-product output costs and cost for the technological norms is what most companies will be interested in for operational reasons.

This information shows deviation from technological standard costs due to inefficient use of existing technology. The non-product output costs at this level can be reduced by better housekeeping, for example, better monitoring of raw material consumption, avoiding scraps and wastes and reducing energy and water consumption. This information needs to be generated on a monthly basis for companies to react faster. Level 2 non-product output costs (BAT) norms need to be generated on a less frequent basis.

This can be used to work out the economic feasibility of performing technological improvement. This information will be used when considering changing technologies between 3-7 years, depending on the technological life cycle of the equipment. Total environmental costs reported must include non-product output costs related to BAT. It is suggested that these costs be calculated annually for internal reporting purposes and to assist managers in making important investment decisions (Schaltegger et al., 2010).

2.1. Benchmarking and controllability of non-product output costs. Schaltegger et al. (2010) define benchmarking as "A benchmark study is a systematic search for processes that yield superior performance. These benchmarks are then compared against current activities to gain insight on how to improve" (MacLean, 2004).

Benchmarks are used in environmental management to compare environmental performance. Benchmarking allows companies to assess their performance and identify opportunities for improvement.

Altham (2007) made a similar argument and extends this notion that benchmarking can increase environmental awareness by identifying environmental aspects that offer greatest potential for economic benefits with limited costs. Furthermore, benchmarking assists managers in identifying areas that incur large environmental costs that could be easily reduced by good housekeeping measures. It can, therefore, be concluded that since benchmarking is a process of continuous searching for best practices in completing tasks, it is also most likely that this could increase an organization's success in adopting Cleaner Production techniques and technologies.

Furthermore, evidence suggests that in order to assist managers in making CP investment decisions, three benchmarking models must be used to compare non-product output costs. A pilot programme for the promotion of Environmental Management through identification of non-product output costs was introduced to case study of Zimboard Mutare, Zimbabwe. Arlinghaus and Berger (2002) found that by implementing action plans to reduce hidden and obvious NPO costs by identifying its original causes, the company achieved economic, environmental, and organizational benefits with little investment. It had been inferred that changes within the company not only increased transparency within the company, but also motivated staff to become more responsible and strive towards further improvements.

Table 1. The Relationship between non-product output costs, controllability and potential savings

	Ability to control cost	Method of controlling cost	Potential cost savings
Non-product output less technological standards	Short term	Good housekeeping measures	Small to medium
Technological standards cost less state-of-the-art standards	Medium term	Switch to state-of-the-art technology	Medium to large
State-of-the-art standards less theoretical costs	Long term	Technological invention	Medium to large
Theoretical costs (chemicals industry)	Medium to long term	Switch to other raw materials and technology	Small to large
Product costs	Long term	Product modifications	Small to large

Table above shows the relationship between non-product output costs, controllability and potential savings (Csutora and Palma, 2009, p. 6).

Csutora and Palma (2009) explained the rationale for using benchmarks to measure inefficiencies against current activities and gain insight on how to improve by making cost reduction options more visible to managers. Life-cycle of technologies needs to be considered when benchmarking environmental costs. BAT is defined at a European level. They further claimed that using this benchmark recognized that some waste and pollution would always be generated even if state-of-the-art technology was used. When existing technology is outdated, even if housekeeping measures are implemented, it is nearly impossible to achieve technological standards of non-product output costs, argued Csutora and Palma (2009). They also reported the possibility of some 5-10% savings being realized by better monitoring and controlling of raw material input by avoiding leaking pipes and wasting energy.

Accountants are familiar with technological standards from the standard costing system. These standards highlight areas where waste and emissions can be reduced by better housekeeping, better monitoring of raw material consumption and reduction in energy and water consumption.

BAT norms reflect the most efficient, environmentally sensitive technological standards that are internationally available. This would require modification of existing technology and are thus only controllable in the medium- to long-term. The cost difference indicates the economic feasibility of performing technological improvements (Schaltegger et al., 2010). Annual calculation and reporting of these costs are suggested to enable new investment decisions by shareholders.

Theoretical norms represent 100% efficiency, which is almost impossible to achieve.

2.2. Future sustainability of boiler plants. The People's Republic of China (2011-2015) has identified 'developing a circular economy' as the strategic area of focus to address the socio-economic development issues relating to waste management. This involves implementation of circular production methods; enhancing circular use of resources and recycling systems; and strengthening policy and technical support (Godfrey, Rivers and Jindal, 2014, p. 6).

The trend towards the circular economy together with the principle of the waste hierarchy is prompting change within South Africa. Currently, South Africa is largely at the peripheral of this global transition.

Strategic evolution towards managing waste such as coal ash within the next 3-10 years, involves research on minimizing ash and clean technologies.

- Technological standards show the best way that current technology can be used. Eco-efficiency is maximized in the short-term provided the technological discipline of line workers is strong. Approached by better housekeeping measures, reducing rejects, avoiding wastage of materials (end-of-life cycle technology is much longer than the depreciation period between 5 to 7 years longer).
- We can also benchmark eco-efficiency to the best practice in the industry (state-of-the-art). BAT standards reflect the best practice in the industry. Replacement of technology in the medium-term would be required.

Large amounts of capital have been invested in CP research and development projects to provide a wide range of boilers to various industries to ensure that sustainability targets are achieved (Kuik, 2006). During a benchmarking study by the Pulp and Paper Research Institute of Canada (2008), the importance of maximum system efficiency was highlighted. It had also been found that maintenance and equipment/technology impact on operating conditions. During research, it had been discovered that many coal-fired plants do not operate according to their design specifications because of poor quality coal, poor plant maintenance and improper diagnostic tools. Savings of millions of tons of coal, reduced CO2 emissions and improved financial performance have been identified as benefits of implementing low cost best practices (Giglio, 2013; Avsar and Demirer, 2008).

The future sustainability of companies generating large amounts of boiler ash containing unburned coal particles is questionable. This hazardous waste has negative impact on the company's environmental and economic performance (Coal fly ash, bottom ash and boiler slag, 2014).

3. Research design and methodology

This research was a case study combined with a causal-comparative research as the aim of the researcher was to understand the reason for the excessive waste generated during the process being investigated.

The causal study was set out to determine whether the technology used in the production process had a negative impact on environmental and economic performance resulting in excessive use of resources and waste being generated due to inefficient production processes. Causal research will identify cause-and-effect relationships among variables when the research problem has been narrowly defined (Yin, 2009). These findings were then compared to technological standards and standards of best available technology. This study aimed at understanding the impact of Cleaner Production technology on the environmental and economic performance of the company.

Documentary evidence was also used to analyze cost allocation methods and cost incurred in steam production process for the period under review.

Documents from the technical department, containing information on coal input and steam output for a period of 12 months, from October 2012 until September 2013, were also analyzed by the researcher to establish operational efficiency of boiler technology used by the company currently.

The technological flow chart analysis provided the necessary information of the input, process and output of the process under observation. These results were compared to the actual raw material input and output of the process to identify inefficiencies.

An Environmental Management Accounting tool, the Material Flow Cost Accounting (MFCA) approach was used to measure the quantity and value of the non-product output costs. These non-product output costs were benchmarked against technological standards as well as Best Available Technology (BAT) standards.

This technique assisted in identifying areas of potential savings for the company in the short-, medium- and long-term. Non-product output costs were calculated using raw material purchase price.

Theory is grounded on the evidence collected. Even though actual data discovered by the researcher may be specific to a specific organization. However, these theories are generalizable in understanding how other organizations function. Explanatory case studies express theoretical and analytical generalizations as opposed to the usual statistical generalization of positivist approach. Analytical generalization exists when a previously developed theory is used as a theoretical framework to compare the empirical results of the case study (Yin, 2009).

A key goal in the data analysis was to ensure that the data supported the findings and conclusions arrived at by the researcher.

3.1. Benchmarking environmental costs. *3.1.1. Method used to benchmark environmental costs.* The aim of this study was to identify potential saving opportunities for the company by benchmarking current environmental costs against technological standards and best available technology. Benchmarking is a systematic search for processes that yield superior performance. These benchmarks are compared against current activities to gain insight on how to improve by using specific technologies. This was done by providing estimates of the maximum amount of financial savings that could be achieved through improving the eco-efficiency for certain technologies.

During the analysis of cost control and cost reduction opportunities in this study, it was necessary to take into account the life – cycle of the technology. Cost control and cost reduction options were classified under three assessment periods, namely, the short-, medium- and long-terms. The following standards were established during cost control classification (Schaltegger et al., 2010; Jasch, 2009):

- Short-term – These cost reduction options are limited by the existing technology until the end of the technological life-cycle is reached, only minor changes of processes and improved housekeeping measures make sense;
- Medium-term – Company can change technology and get closer to the state-of-the-art of the industry; and
- Long-term – State-of-the-art technology may improve and get closer to the ideal world. No harmful emissions are produced.

The benchmarks used in this study were technologically determined. The scope of this study was limited to the utilities department. This research focused primarily on the company's boilers. Therefore, environmental costs referred to during the study are limited to the non-product output generated by the boilers.

It had been decided to adopt a Material Flow Cost Accounting (MFCA) method to calculate the value of the non-product output. In previous studies, and it had also been established that material purchase cost was most significant cost of non-product outputs (Schaltegger et al., 2010). Data of the actual material input and output over a 12-month period (financial year starting in October 2012 to September 2013) were used as a sample. Actual standards were compared to and benchmarked against two other standards, namely, technological standards of the boilers as well as best available technology (BAT standards) or state-of-the-art technological standards.

3.2. Benchmarking non-product output cost. In this study, total non-product output costs included material purchase value of wastes; costs of processing; handling and warehousing wastes; and treatment and disposal.

Material purchase value of the waste was found to be the overwhelming majority of the costs. Potential benefits in terms of savings were revealed during this analysis.

3.2.1. Environmental Management Accounting data collected using material balance to calculate value of non-product output costs. Non-product output was identified and quantified by applying the Material Flow Cost Accounting methodology. This highlighted sources and causes of waste and emissions and potential savings of adopting Cleaner Production was identified. Material purchase price was used to calculate the value of non-product output in this study.

Actual material flows was quantified and found to differ from those suggested in the technological flowchart in the manual compiled by the designers of the technology.

A detailed analysis of Cleaner Production Assessment (CPA) was completed. Only materials which become part of the final product should be taken into account when calculating product costs. Therefore, non-product output costs took into consideration the entire value of material/energy inputs that did not become integral parts of the final product. This was then classified under short-, medium-, and long-term, according to their controllability. This information was used to support CP measures and in planning investments in new cleaner technology.

Material purchase value of raw material input was used to cost the non-product output. Production cost should exclude the cost of material that is wasted or becomes material loss.

Current cost in steam production is benchmarked against the cost of production using cleaner technologies. This calculation is used to assess and evaluate the economic and environmental benefits of CP.

Cost appraisal of investing in Cleaner Production technology is provided to assist in the decision making process.

4. Data analysis and discussion of findings

The company's material losses are not evaluated and added to non-product output costs. All raw materials used are allocated to product cost irrespective of whether they actually form part of the final product. Energy and system costs, as identified by MFCA, are also not considered when costing wastes. Therefore, no decisions are made towards improving production processes and moving towards Cleaner Production technology. The cost of investing in CP technology is not justified, due to the inaccurate assessment of environmental costs resulting in it being underestimated. Environmental costs are also reflected under general overheads account and are not being traced back to the product or process.

The company uses traditional costing systems and has not yet implemented an EMA system. Schmidt and Nakajima (2013) found some weaknesses in conventional Cost Accounting in that it cannot give all the required data. Monetary value flows are traced and interpreted as product cost in a Conventional Cost Accounting (CCA) system. Reporting under MFCA highlight actual production costs by excluding the cost of raw material purchased that becomes waste and does not form part of the final product. Generally, companies focus on the input materials and the quantity of products produced from these inputs, not on the material losses generated from the specific process.

4.1. Coal input and steam production output of boilers. Data from the input/output schedule of the steam production process for the period under review (October 2012 to September 2013) are used to test the efficiency of the boiler technology against technological standards and BAT standards.

According to technological standards of the company's current boiler technology, the standard of input/output ratio of coal and steam generated is 1:7. However, the input/output schedule (Appendix 1) indicates the actual amount of coal used for the 12-month period. This ratio is compared to technological standards of 1:7 to identify technological inefficiencies of the steam generation process. BAT standards for more efficient boilers of 1:8, as identified by boiler technology experts (Martin Speek, John Thompson Boilers, 2014), is compared to actual standards to identify medium-term saving opportunities that the company could enjoy if they consider replacing existing technology with state-of-the-art boilers.

Statistical testing of the data revealed that the three means are significantly less than the standard of 7. This implies that the company's current technology is not operating according to design specification. This is therefore, a sign of an inefficient production process.

In comparison to Test Standard 1:8 (BAT standards according to boiler technology expert) the following one-sample statistics was found.

The results follow a similar pattern for the standard of 1:8. This means that company's current standards are much lower than BAT standards, which implies greater saving potential should the company replace their existing boilers with state-of-art boiler technology.

This can be used to work out the economic feasibility of performing technological improvement. This information will be used when considering changing technologies between 3-7 years, depending on the technological life cycle of the equipment. It is suggested that these costs be calculated annually for internal reporting purposes and to assist managers in making important investment decisions (Schaltegger et al., 2010).

4.2. Correlations. Bivariate correlation was also performed on the (ordinal) data. The results indicate the following patterns:

Positive values indicate a directly proportional relationship between the variables, and a negative value indicates an inverse relationship. All significant relationships are indicated by a * or **.

For example, the correlation value for business factors between "Integrated environmental issues are incorporated into the company's strategic planning process" and "Environmental objectives are linked with the company's corporate goals" is 0.721. This is a directly related proportionality. Respondents agree that the more integrated environmental issues are incorporated into the company's strategic planning processes, the more likely the environmental objectives are linked with the company's corporate goals, and vice versa.

Respondents also agree that the allocation of environmental-related costs to production processes and classification of environmental-related costs results in improvements to environment-related cost management (correlation of 0.880 and 0.978, respectively).

Further analysis shows that assessments of environmental impact issues during capital investment decisions demonstrate greater commitment and awareness of environmental issues by the business managers (positive correlation of 0.748). Input and raw material waste seem to be positively related to poor manufacturing.

Respondents agree that improper use of technologies is directly related to insufficient operator training and commitment (positive correlation of 0.964). In addition, findings reveal that old technologies used in production indicate management's resistance to change (positive correlation 0.701).

Negative values, as identified in the correlation results, imply an inverse relationship. That is, the variables have an opposite effect on each other. Analysis on negative coefficients for certain variables was interpreted as follows:

The coefficient between "The fear for business sustainability in the future and its uncertainties" and "Classification of environment-related costs" is -0.664.

These findings indicate that the greater are the environmental business costs, the less sustainable businesses may become, and vice versa.

Interestingly, a negative correlation exists between inclusion of environmental information in the present Management Accounting information system and input and raw material waste. This means that input and raw material waste decrease when environmental issues are incorporated into the company's Management Accounting System (-0.656). This trend indicates an inverse relation between Environmental Management activities practised and input and raw material waste generated. Hence, by incorporating Environmental Management activities into daily business operations, input and raw material waste generated can be reduced and manufacturing can be improved.

4.3. Summarized overview of quantitative findings. Findings also reveal that not all environmental aspects are quantified, and limited quantified data make it difficult to monitor environmental performance and identify possible environmental improvements.

The objectives in the strategic plan of the organization correspond to the national environmental quality objectives.

This implies that environmental issues are incorporated into the long-term goals of the organization which requires a strategic work plan to be implemented and budgeted.

There is a need to increase pressure on business managers to include environmental objectives in the operational planning, which seems to be currently lacking in the company. Operational activities need to be aligned to strategic objectives.

The effectiveness of the company's current system from an environmental point of view is questionable since it is difficult to assess the extent to which environmental objectives are fulfilled.

Environmental objectives in terms of targets and improvement measures are not clearly connected to the strategic objectives and absent from the general management system. Research suggests that even though a company may have well-formulated objectives and suitable indicators measuring progress towards achieving objectives, actual improvements are unlikely to be achieved unless employees are committed and motivated to work towards improving environmental performance (Lundberg, 2009).

Managers in the company are unaware of the company's progress and performance to environmental objectives due to a lack of feedback and unclear structures.

4.3.1. Identify possible causes of waste generation from the steam production process. During the steam generation process, large amounts of unburned coal are found in the bottom of the boiler ash. Hence, the steam production process is inefficient, resulting in excessive raw material wastage. Input/output ratio according to technological design is not being achieved. Therefore, the amount of coal used to generate steam is in excess to what is prescribed in the technological flow chart manual.

The information above indicates that the three of the four boilers are functioning well below test standards of 1:7 and state-of-the-art technological standards of 1:8. The only boiler that is functioning close to the design specification is boiler two. In order to identify operational savings, managers need to look at ways to reduce the non-product output costs caused by sub-optimal functioning of boilers.

It should be noted that the total cost of material losses was limited to raw material flow only. Material purchase value of non-product output is the most significant of all costs incurred in steam generation process.

Unburned coal/carbon content of boiler ash (solid waste) has been estimated to identify non-product output costs of raw materials that do not form part of the final product (steam). Material loss/waste is quantified and calculated using the purchase price of coal. Monetary value of non-product output is calculated using the equation as follows:

Monetary value of loss = quantity loss in tons x input price of coal.

4.4. Analysis of accounting documents and records. *Accounting documents and records were analyzed to identify production costs and non-product output costs of steam generation process. The aim of this research is to identify potential saving opportunities by introducing Cleaner Production techniques and technologies.*

Note: There are two major costs considered significant in the steam generation process and would be used in calculation of payback period for investing in new boilers or upgrading existing boilers to improve efficiency. The costs are as follows:

- Cost of disposal of bottom boiler ash to landfill (transportation and handling cost of waste), and
- Loss of raw material (coal) due to inefficient processing (calculated using MFCA model proposed, which is a tool of EMA).

4.4.1. The non-product output value is calculated as follows:

Material purchased (coal) – R 70 923 659.11.

Non-product output (unburned coal in the form of waste – 20% loss) – R 14 184 731.82.

4.5. Loss due to technological inefficiency. Input/output ratio in tons of coal used to generate steam is 7. This ratio is based on technological standards of industrial boilers. However, the company output ratio is approximately 6.3. This indicates inefficient use of resources in the production process. Hence, more input is required per output generated. This has a negative impact on the environment and also increases the costs of resources for the company.

The financial loss has been evaluated to an amount of approximately R 500 000 per month, resulting in a total loss estimated to R 6 million per annum (Cost accountant, 2014)

4.6. Cost benefit analysis. *Cost: loss of material, financial loss due to downtime of boilers and cost of disposal of waste, loss due to technological inefficiency (approximately 1 year).*

Note:

- John Thompson Boilers were consulted to estimate values for cost of replacing boilers and upgrading the back-end equipment to reduce emissions and improve boiler efficiency and performance.
- It should be noted that amounts used were estimated as actual values and will depend on what the customer actually wants and which would be best suited to the industry. Each boiler is designed specifically to meet the needs of individual companies.

TOTAL COST:

1. New boiler = R 60 000 000.00 per boiler (approx. R 240 million),

2. Boiler upgrade = R 5 000 000.00 per boiler (approx. R 20 million).

TOTAL SAVINGS: Material lost (non-product output value based on 20 percent loss of coal during steam generation process) = R 14 184 731.82.

4.6.1. Calculation of boiler efficiency is as follows: Input/output efficiency of current technology for the period under review was: 1 ton coal: 6.3 tons of steam (amounts reflected in the accounting records will be used in this calculation).

Technological standard: 1 ton coal: 7 tons of steam = 1/7 = 0.143.

Table 2 shows the estimated total saving opportunity should technological standards be achieved.

Table 2. Total estimated savings based on technological standards

Non-product output value due to inefficient production process at 10 percent excess material lost (expected loss during process is 10 percent)	R 7 092 366.00
Loss due to input/output standards below technological standards of 1:7	R 1 825 000.00
Disposal cost	R 2 352 000.00
Cost incurred in hiring of pay loader estimated (2hrs a day @R 500 per hour)	R 240 000.00
ESTIMATED TOTAL SAVINGS	**R 11 509366.00 per annum**

Table 2 shows that the estimated saving opportunity of R 11 509 366.00 is possible should the company implement measures to achieve technological standards. Technological standards may be achieved by upgrading existing boiler technology to ensure that boilers function according to design specification. The cost of upgrading the company's existing boilers in order to achieve technological efficiency standards was estimated at an amount of approximately R 5 000 000 per boiler. This estimated value was established during the interview with John Thompson boiler manufacturers. Payback period for the upgrading was calculated on the estimated cost of R 20 000 for the four boilers.

Equation to calculate payback period:

Total investment cost/Estimated total savings per annum.

Replacement costs of boilers are extremely high. Therefore, upgrading costs will be used in calculating payback period. This will be used in strategic decision-making process.

Payback: R 20 000 000/R11 509 366 = 1.74 years,

Efficiency level using newer, upgraded technology is 1 ton coal: 8 tons steams,

Savings in reduced raw material consumption = 1/8 = 0.125.

Table 3. Boiler efficiency calculation based on state-of-the-art standards

Coal usage	517 938 tons (actual steam) x 0.125 = 64 742 tons
Actual coal usage – budgeted usage	76 022 tons – 64 742 tons = 11 280 tons
Material purchase value	11 280 tons x R933 = R 10 524 240 (savings)
Payback calculated using raw material savings only	R 20 000 000/10 524 240 = 1.9 years
Payback period calculation including savings on disposal costs	R 20 000 000/13 116 240 = 1.5 years

Table 3 shows the difference in actual coal usage and coal usage based on state-of-the-art technological standards. This indicates the efficiency levels and possible savings for the company should they replace their current boilers with state-of-the-art boilers.

Table 4. Total monetary value of loss in steam generation process based on technological standards and state-of-the-art standards

ACTUAL COAL USED	ACTUAL STEAM GENERATED IN TONS	STEAM GENERATED BASED ON TECHNOLOGICAL STANDARDS	STEAM GENERATED BASED ON STATE-OF-THE-ART STANDARDS	TOTAL COST OF STEAM GENERATION PROCESS IN TONS
76022 TONS	517938	532154	608176	R 181.87 PER TON
LOSS IN HEAT (STEAM) IN TONS		(14216)	(90238)	
LOSS OF STEAM IN MONETARY VALUE @ R 181.87 PER TON		R 2 585 463.92 per annum	R 16 411 585.06 per annum	

Table 5. Estimated saving in total production cost of steam generation process based on above standards and reduce coal usage

	CURRENT STANDARDS	TECNOLOGICAL STANDARDS	STATE-OF-THE-ART STANDARDS
PRODUCTION COST PER TON OF STEAM	181.87	178.22	161.56
TOTAL PRODUCTION COST	94 196 108.09	92 306 051.98	83 676 734.98

Table 6. Environmental benefits of reduced coal usage – GHG's @ 2.56 emission level per ton of coal (IPPC)

	TECHNOLOGICAL STANDARDS	STATE-OF-THE-ART STANDARDS
GHG EMISSION REDUCTION	2031 X 2.56 = 5199	11280 X 2.56 = 28877

Table 7. Saving in total production cost based on above calculation for period under review (estimated)

Transportation cost @ R 2000 per 10 ton waste (boiler ash) to landfill:

SAVINGS IN TONS	TECHNOLOGICAL STANDARDS	TOTAL SAVINGS IN ENVIRONMENTAL COSTS
Approximately 200 tons = 20 x 10 ton loads disposed to landfill at a cost of R 2000 per load	R 40 000 disposal costs	R 189 005.61 + R40 000= R 229 005.61

Table 8. Saving in total production cost based on above calculation for period under review (estimated)

SAVINGS IN TONS	STATE-OF-THE-ART STANDARDS	TOTAL SAVINGS IN ENVIRONMENTAL COSTS
Approximately 1130 tons = 113x 10 ton loads disposed to landfill at a cost R 2000 per load	R 226 000 disposal costs	R 1 051 937.31 + R 226 000= R 1 277 937.31

Table 7 shows the higher disposal costs due to boiler operating below technological standards.

Table 8 shows that boilers are operating below technological standards and that there is significant saving potential by switching to state-of-the-art technology in the future.

Figure 1 shows the tons of steams generated at different efficiency levels (indicated by coal usage)

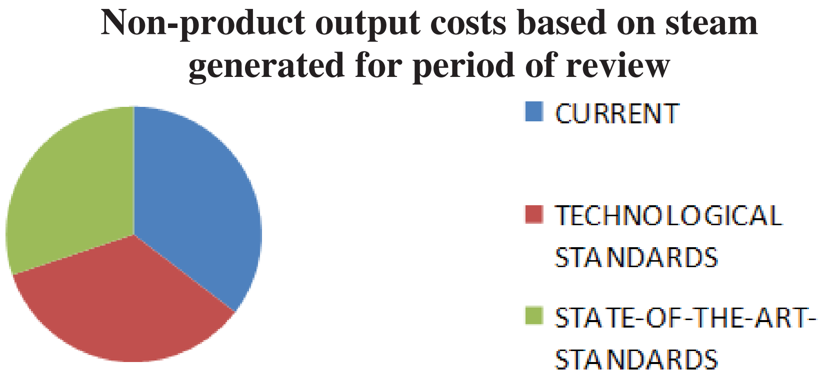

Fig. 1. Steam generated non-product output costs

Figure 1 indicate that the amount of non-product output costs is reduced if technological standards are achieved and much lower when state-of-art technology is used in steam generation process. This can result in savings in input resource use for the company.

State-of-the-art technological standards of 1:8 were established by most advanced boiler makers in the industry, John Thompson Boilers (Jeremy Edgar, 2014).

Conclusion

Costs of waste disposal were not consistently gathered and evaluated and the cost of handling of waste within the organization was seldom taken into account. Material purchase value included in waste was theoretically accepted but was never actually calculated. It had also been found that environmental and technical managers have insufficient information about the magnitude of operational costs. Only accountants were exposed to this kind of information. Hence, there is a need for increased awareness of the magnitude of environmental costs, more especially, the material purchase value of non-product output contained in waste needs to be established. This information could be used to implement measures to improve material and process efficiency.

Therefore, it can be deduced that the environmental costs reflected in the company records are incorrect as most of the costs that should be included in the cost calculation are omitted.

The reason for this is strongly attributed to the conventional accounting system being used by the company.

To benchmark the company's current environmental cost by comparing material balance against technological standards and best available technology. Benchmarks used in this case study to compare non-product output were limited to technological standards and BAT standards for boiler technology. Evidence has been found that has identified material purchase value of non-product output as the category of EMA that has the potential of largest cost savings as stated by Jonall (2008). Good housekeeping measures of CP focus on getting closer to the technological non-product output costs. Savings of approximately of between 5 to 10% by monitoring and controlling raw material consumption have been reported in previous cases (Schaltegger et al., 2010).

Environmental and economic benefits achievable through benchmarking. Table 6 indicates the possible saving opportunities by benchmarking environmental costs to technological standards and state-of-the-art standards.

Table 6. Opportunities by benchmarking

	TECHNOLOGICAL STANDARDS	STATE-OF-THE-ART STANDARDS
SAVINGS DUE TO REDUCED RAW MATERIAL (COAL) CONSUMPTION	R 1 890 056.11	10 519 373.11
REDUCED LOSS IN TONS	2031 @ 10% = 203.10 TONS	11280 @ 10% = 1128 TONS
REDUCED NON-PRODUCT OUTPUT VALUE (WASTE) 10 (percent loss of material purchased value loss)	R 69 033 603.00 @ 10% LOSS R 6 903 360.30 – (7 092 365.91) = R 189 005.61	R 60 404 286.00 @ 10% LOSS R 6 040 428.60 – (7 092 365.91) = R 1 051 937.31

Table 6 clearly shows that there are opportunities to improve environmental and economic performance of the organization by ensuring that technological standards are achieved in the short-term and by moving closer to state-of-the art technologies in the medium-term.

The objective of this study has been achieved.

To make recommendations that will assist the company in their decision making process.

Recommendations

The final objective of the study was to make recommendations that will assist the company in their decision making process.

Results indicate that the current production process is inefficient and has impacted negatively on the company's environmental and economic performance. In light of the new legislation on waste management and increased competition in the industry, the company needs to make informed strategic decisions to ensure the future sustainability of the organization.

Recommendation 1. The researcher recommends the following measures to improve boiler performance and reduce environmental impact:

Benchmarking environmental costs in short-, medium-, and long-term. ***Short-term measures.*** Investment in Cleaner Production technologies is expensive, however, in order to improve environmental and economic performance organizations need to adopt a Cleaner Production strategy. Therefore, it is advisable that in the shorter-term the company must ensure that their current technology is operating efficiently and according to technological standards. By proper housekeeping and regular maintenance of their current boilers the company would be able to save R 7 092 366 (as expected loss of coal is 10%). Excess carbon present in the waste indicates poor operational practices. The company would also reduce the cost of disposal of ash to landfill and since disposal of carbon to landfill is prohibited, this would ease off the environmental burden to the company.

Long-term measures. In the long-term the company should consider adopting Cleaner Production technologies.

Current estimated cost of replacing old boilers according to Jeremy Edgar (John Thompson Boilers, 2014) is approximately R60 million per boiler (total of R240 million investment). This strategic decision will require input from all stakeholders considering the high investment cost.

It can, therefore, be concluded that the company can improve both economical and environmental performance by ensuring that technological standards are achieved in the short-term.

Greater savings can, however, be achieved by investing in Cleaner Production technology in the medium to long-term. This will result in higher environmental and economic performance, efficient resource consumption and improved competitive advantage being achieved by the company.

References

1. Abdel-Kader, G.M. (2011). *Review of Management Accounting Research*, United Kingdom. Palgrave Macmillan, pp. 63-65.
2. Altham, W. (2007). Benchmarking to trigger cleaner production in small businesses: dry cleaning case study, *Journal of Cleaner Production* (online), 15, pp. 798-813. Available: http://www.sciencedirect.com.
3. Arlinghaus, S. and Berger, C. (2002). *Application of environment-oriented cost management (EOCM) in a particle – and fireboard company*. A case study of Zimboard Mature, Zimbabwe. Pilot programme for the Promotion of Environmental Management in the Private Sector of Developing Countries (P3U) (online). Available: http://www.gtz.de/p3u.
4. Avşar, E. and Demirer, G.N. (2008). Cleaner production opportunity assessment study in SEKA Balikesir pulp and paper mill, *Journal of Cleaner Production*, 16 (4), pp. 422-431.
5. Benchmarking energy use in Canadian Pulp and Paper mills (2008). Pulp and Paper Research Institute of Canada. p. 37.
6. Berkel, R. (2011). Evaluation of the global implementation of the UNIDO-UNEP National Cleaner Production Centres, *Clean Technologies and Environmental Policy*, 13 (1), p. 161.

7. Bras, B., Realff, M. And Carmichael, C. (2004). Integrated Environment and Economic Performance Assessment for Strategic Planning and Policy Analysis in Paper Manufacturing. CPBIS project – B-4: 5-7, *final project report to CPBIS*.
8. Christmann, P. (1999). Effects of "Best Practices" of Environmental Management on Cost Advantage: The Role of Complementary Assets, *Academy of Management Journal, Special Research Forum on Organizations and the Natural Environment*.
9. Csutora, M. and De Palma, R. (2009). *Using EMA to benchmark environmental costs – theory and experience from four countries through the UNIDO test project* (online), pp. 143-162. Available: http://www.springerlink.com/content/x5t538821256l12k/.
10. Despeisse, M., Oates, R.M., and Ball, D.P. (2013). Sustainable manufacturing tactics and cross-functional factory modeling, *Journal of Cleaner Production*, 42, pp. 31-41 (online). Available http://www.sciencedirect.com/science/article/.
11. Domil, A.E., Peres, C., and Peres, I. (2010). Capturing environmental costs by using activity based costing method, Economic Science Series (online), XVI, pp. 719-726. Available: http://www.ceeol.com (Accessed 10 October 2013).
12. Environmental Sustainability Performance (ESP) Benchmarking (online) (2013). Available: http://www.benchmarking-sustainability.asp (Accessed 2 July 2013).
13. Fore, S. and Mbohwa, G.T. (2010). Cleaner production for environmental conscious manufacturing in the foundry industry, *Journal of Engineering Design Technology*, 8 (3), pp. 314-333 (online). Available http://dutlib.dut.ac.za:2057/docview/1012253156 (Accessed 21 June 2013).
14. Giglio, R. (2013). *Is CFB the key to scaling up biomass?* Power Engineering International (online), 21 (10), 32, pp. 34-36.
15. Godfrey, L., Rivers. M., and Jindal. N. (2014). A National Waste R&D and Innovation Roadmap for Soth Africa: Phase 2 Waste RDI Roadmap. Trends in Waste Management. Department of Science and Techno logy: Pretoria. Available online URL: http://www.wasteroadmap.co.za (Accessed 23 April 2014).
16. Henriques, I. And Sadorsky, P. (2007). *Environmental Technical and Administrative Innovations in the Canadian Manufacturing Industry*, Business strategy and the environment (online), 16, pp. 119-132. Available at: http://www.interscience.wiley.com (Accessed 10 July 2013).
17. Hyrslova', J., Vagner, M., and Palasek, J. (2011). Material Flow Cost Accounting (MFCA) – Tool For The Optimization of Corporate Production Processes, *Business, Management and Education*, 9 (1), pp. 5-18.
18. Jasch, C. (2009). Environmental and Material Flow Cost Accounting Principles and Procedures (Eco-Efficiency in Industry and Science Series, 25, *Journal of Industrial Ecology*, Springer science and Business Media: Berlin, pp. 832-834.
19. John Thompson: Utility Boilers and Environmental Solutions. Available online URL: http://www.johnthompson.co.za/utilityboilers.php (Accessed 22 March 2014).
20. Jonall, P. (2008). *Environmental Management Accounting (EMA), Management Accounting including Environmental Management*, 2.
21. Kuik, O. (2006). *Environmental innovation dynamics in the pulp and paper industry*. A case study in the framework of the project 'Assessing innovation dynamics induced by environmental policy'. European commission, DG Environment.
22. Lagioia, G., Tresca, F. A., and Gallucci, T. (2014). *Adoption of the Material Flow Cost Accounting (MFCA) approach to integrate physical and monetary data in small enterprises for waste-reduction decisions*. Evidence from Italy (online). Available: http://www.academia.edu/5849899.
23. Lambert, S. C., Carter, A.J., and Burritt, R.L. (2012). *Recognising commitment to sustainability through the Business Model*, Centre for Accounting, Governance and Sustainability. University of South Australia.
24. Lundberg, K. (2009). Monitoring as an instrument for improving environmental performance in public authorities. Doctoral thesis. KTH – Environmental Management and Assessment Research Group. Department of Land and Water Resources Engineering. Royal Institute of Technology (KTH), Sweden.
25. MacLean, R. (2004). EHS organizational quality: A DuPont case study, *Environmental Quality Management*, 14 (2), pp. 19-27.
26. Nakajima, M. (2006). The new management accounting field established by Material Flow Cost Accounting (MFCA). *Kansai University review of business and commerce*, 8, pp. 1-22.
27. Pandey, A.K. and Brent, A.C. (2008). Application of technology management strategies and methods to identify and assess cleaner production options: cases in the South African Automotive industry, *South African Journal of Industrial Engineering*, 19 (2), pp. 171-182.
28. Pons, M., Bikfalvi, A., Llach, J., and Palcic, I. (2013). Exploring the impact of energy efficiency technologies on manufacturing firm performance, *Journal of Cleaner Production,* 52, pp. 134-144 (online). Available: http://elsevier.com/locate/jclepro (Accessed 1 June 2013).
29. Radonjič, G. and Tominc, P. (2007). The role of environmental management system on introduction of new technologies in the metal and chemical/paper/plastics industries, *Journal of Cleaner Production*, 15 (15), pp. 1482-1493.
30. Schaltegger, S. and Csutora, M. (2012). Carbon accounting for sustainability and management. Status quo and challenges, *Journal of Cleaner Production*, 36, pp. 1-16.

31. Schaltegger, S., Bennett, M., Burritt, R.L., and Jasch, C. (2010). *Eco-efficiency in industry and science. Environmental Management Accounting for Cleaner Production*, 5th edition. Springer Science and Business Media. UK.
32. Schmidt, M. And Nakajima, M. (2013). Material Flow Cost Accounting as an approach to improve resource efficiency in manufacturing companies. Resources (online), 2, pp. 358-369. Available: http://www.mdpi.com/journal/resources.
33. Stringer, L. (2010). *The Green Workplace- Sustainable strategies that benefit employees, the environment, and the bottom line*, Paperback edition. New York: Palgrave Macmillan.
34. V`an, H. (2012). *Environmental benefits and its statement in Environmental Management Accounting*. Ph.D. University of Szeged.
35. Yin, R.K. (2009). Case Study Research Design and Methods. Sage Publications London United Kingdom. 4th Edition volume 5, Applied Social Research Methods Series.

Appendix 1

Table 1A. Input/output schedule of raw material used and steam generated

Date	Boiler 1		Boiler 2		Boiler 3		Boiler 4	
	Coal (tons)	Steam (tons)	Coal (tons)	Steam (tons)	Coal (tons)	Steam (tons)	Coal (tons)	Steam (tons)
Oct-12	1888	12630	1732	11106	1712	11706	1707	11584
Nov-12	1900	12684	1882	11673	1277	8845	1778	12066
Dec-12	1691	11095	2085	13195	1191	7727	1608	10431
Jan-13	1929	12648	2130	13559	1454	8506	1476	9446
Feb-13	1298	8565	1822	12214	705	4181	1395	9341
Mar-13	1968	13434	1466	9294	427	2031	105	679
Apr-13	1061	7574	1965	11853	1898	13815	998	7092
May-13	2364	16640	248	1694	2152	15359	1855	12790
Jun-13	2191	14916	1740	12291	1415	9956	954	6691
Jul-13	2361	15669	2518	1485	1979	12561	872	5426
Aug-13	2275	13924	2438	31091	1743	10741	1789	10675
Sep-13	1648	11240	2274	15383	1258	7747	1570	9595
Total	22573	151019	22299	144837	17210	113176	16108	105816

Appendix 2

Article on Benchmarking:

- Transport and labor = estimated to be approximately R 2 000 per 10 ton load of ash to dispose off at landfill 5 km away from mill (General manager DCLM 2014). Approximately 1960 tons of boiler ash disposed off by the plant monthly.
- Total transportation cost @R 2 000 per 10 ton load = R 392 000 per month and R 4 704 000 per annum. Standard waste generated during this process is approximately half this amount (Jeremy Edgar, 2014).
- Therefore, an estimated amount of R2 352 000 per annum represent additional disposal cost incurred by the company due to technological and production inefficiencies.
- The opportunity cost for the beneficial use of the ash, assuming ash probably has similar properties since boilers used in sugar mill, is similar to boiler used in the paper mill (sugar mill boiler ash is sold as road and driveway base or road use within 10 radius of the mill is R 600 per 10 ton truck load).
- Opportunity cost estimated @R600 per 10 ton load of ash = R 117 600 per month and R 1 411 200 per annum. This amount will not be included in the payback period calculation but needs to be considered by management as a shorter-term measure to generate revenue for the by-product instead to disposing it to landfill. This decision could improve both the economic and environmental performance of the company.
- Pay loader hired for approximately 2 hrs per day to load the ash from hopper onto truck is approximately R 3500 per day (Environmental manager, 2014).
- Other environmental cost – nil.

Note:

The boiler ash was not as yet tested for beneficial use as a budget needed to be approved for this process. This testing could only be done overseas and is expected to cost approximately R 30 000. At the time of the study, management was in the process of authorizing fund approval for the test. Therefore, accurate beneficial use of the coal ash could not be stated. The researcher decided to use and estimated value for calculating opportunity cost based on the type of boiler used. During research, the most frequently reported use for bottom boiler ash was as road base and driveway use.

- The current market rate for 10 tons of bottom ash was used to estimate the opportunity cost of this by-product.