Cause Assessment Base Analysis With A View To Enhancing Eco-Efficiencies Using A Cleaner Production Approach: An Investigation Into A Beverages Manufacturing Company In Zimbabwe

IgnatioMadanhire, Kumbi Mugwindiri, Bhekimpilo Ndhlovu

Abstract: - This research study investigates implementable eco-efficiency opportunities available in a beverage manufacturing entity. It recommends actions to reduce material intensity by cutting water usage, cut energy intensity by reducing energy use as well as identify areas of reducing toxic discharge intensity in the plant for continuous improvement. The results of these sustainable programs are compared to the world class beverage bench marks. The study can be a useful resource to plant managers seeking to achieve environmental efficiency in food and beverage manufacturing operations.

Keywords: - beverage, plant, eco-efficiency, energy, water, toxic discharge

1. INTRODUCTION

Competition from regional manufacturers is threatening the success of the local beverage industry in terms of competitiveness, unless it adopts proven strategy of eco-efficiency concepts. The application of eco-efficiency principles have advanced greatly throughout the world. Industry, for example, has had considerable success in reducing pollution and emissions, and eliminating hazardous materials from production processes [1]. In the past, business viewed the environment and sustainable development as problems and risk factors. Today, they are also seen as opportunities – sources of efficiency improvement and growth. Eco-efficiency is very much a part of this picture [6]. Basically, it is about doing more with less: delivering more value while using fewer resources. Companies have realized that if they save energy, for example, they cut the energy cost while also reducing unwelcome outputs such as emissions [10]. Today's business environment demands corporations to act fast in finding effective solutions to problems given the myriad of challenges they face. The challenges include the impact of climate change on business practices, natural resource consumption, chemical pollution and technological change [3]. The forces of globalization, heightened concerns about the deteriorating quality of the physical environment and increased stakeholder power are also increasingly having a real influence on business practices.

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2. JUSTIFICATION

The expansion of human activity and associated loss of natural habitat are the leading causes of the unprecedented extinctions of plant and animal species. This loss of biological diversity leads to instability of ecological systems, as evidenced by climate change [2]. The same pressures are hastening the destruction of vast forest areas and loss of wildlife habitat. The loss of forests also reduces the ability of the ecosystem to combat global warming. Carbon dioxide that would be absorbed by trees instead stays in the atmosphere. Thus emissions of greenhouse gases, such as carbon dioxide, are rising rather than falling [3]. Given the trends in population, energy and resource consumption, combined with technological innovations, the adverse human impact on the global ecosystem is taking its toll on the environment. In 2002, an international meeting held in Johannesburg established that in order to reach a sustainable development there is need to promote sustainable consumption and production of goods. Hence the main goals being to help corporations to develop greener business strategies [3].

3. ECO-EFFICIENCY CONCEPT

Eco-efficiency is practiced by organizations to encourage the search for environmental improvements. It is therefore a part of a society striving for sustainable development. The concept includes directly ecology and economy as well as the third element which is social progress, through improving the environmental and economic situation in the society [7]. Eco-efficiency seeks to accomplish environmental improvements which are economically competitive to others. As well as to become more efficient by creating more value while reducing material and energy consumption and thereby reduce the overall emissions. Eco-efficiency assessment is a tool companies may use in order to evaluate their products or services from environmental and cost perspective. The tool provides the possibility to compare two or more products, processes, activities or plants in order to find the most eco-efficient alternative [5]. In practice, eco-efficiency is achieved through a variety of strategies such as improving material and energy efficiency of products, reducing environmental and human health related risks of industrial processes, designing products which 'fit' into ecological cycles and can be easily disassembled and recycled, and extending the durability, service life and functionality of products [11]. Eco-efficiency is a key element for promoting changes in the way organizations produce and consume resources, and for measuring progress in green growth. Eco-efficiency of production refers to the capability to produce goods and services by polluting the environment and using natural resources and energy as little as possible. At present, the improving of eco-efficiency is considered as an important competition strategy and firms to enhance their profitability with it. Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing the ecological impact and resource intensity throughout the life cycle to a level at least in line with the Earth's carrying capacity. Any company wanting to become eco-efficient strives to improve in the following seven aspects) [11]:

- Reduce the material intensity of its goods and services
- Reduce the energy intensity of its goods and services
- Reduce the dispersion of any toxic material
- Enhance the recyclability of its materials
- Maximize the sustainable use of renewable resources
- Extend the durability of its products
- Increase the service intensity of its goods and services.

Eco-efficiency complements other management approaches by drawing a positive link between environmental improvement and bottom line benefits. It focuses much on value creation , on resource use and pollution reduction [6]. The following equation merges value and ecological aspects into an efficiency ratio as below [4]:

$$\text{Eco Efficiency} = \frac{\text{Product or Service Value}}{\text{Environmental Influence}}$$

Where eco-efficiency variables used are:

Product or service value

- Mass or number of products or services produced or sold; and
- Net Sales

Product or service creation environmental influence

- Energy consumption
- Material consumption
- Net water consumption
- Greenhouse gas emissions
- Ozone depleting substance emissions

3.1 Cleaner production

Cleaner production (CP) refers to the continuous application of an integrated preventive environmental strategy to processes, products and services, to increase efficiency and to reduce risks to human being and the environment [7]. CP requires applying know-how, improving technology and changing people's attitudes in the way people conduct their businesses. This can be applied to the production process and to the products, to preserve raw materials and energy, to eliminate toxic materials, and to reduce the quantity and toxicity of all emissions and wastes before they leave the process. For products, the strategy focuses on reducing impacts along the entire life cycle of the product, from raw materials extraction to ultimate disposal of the products.

3.2 Environmental pressures

Some companies view environmental regulations as barriers to productivity growth and have no support for this opinion. While some have realized it is an advantage to be ahead of regulations through avoiding ad hoc actions. Regulations will always be behind best practice hence need for companies to take the lead in areas such as the environment instead of being put into the defensive mode all the time[6].

3.3 Waste prevention targets

In the country, the Environmental Management Agency (EMA) is empowered by the regulations that allow it to set waste prevention targets with regard to the emission and disposal of waste by any organization or individual. These may relate to [3]:

- Acceptable levels of emissions and disposal of waste
- Design of products containing few pollutants
- Development of products in such a form that residuals can be recycled
- The incorporation of recycled materials in the manufacture of certain products
- The creation of distribution modes that reduce residual waste to a minimum.
- The consumption of products such that little waste is generated.
- The preferential procurement by government agencies of products that cause little pollution after consumption or on becoming waste.

3.4 Energy and energy supply costs

Manufacturing companies mainly rely on hydro electricity as the main source of electricity. A significant portion of the electricity generated in the country comes from thermal generation through the use of coal as the fossil fuel. The danger of greenhouse gases, generated through the use of fossil fuels used to generate electricity is now a well documented case [9]. Energy is the greatest of all utility costs, despite the low unit cost, so significant savings are possible; it therefore makes economic sense for Zim Beverages Co to minimize energy consumption.

3.5 Packaging

Zim Beverages Co is facing increasing pressure to develop and use packaging that reduces the consumption of resources, enables reuse or recycling, and minimizes landfill disposal. Local beverage manufacturing companies in the country have joined forces and formed a company called PETCO which specialize in the recycling of plastic packaging material.

3.6 Waste strategy

Poor waste management, including the management of hazardous waste from industrial activities, are among the key urban problems in the country. The pollution of the country's water systems, air and the general environment is increasing and requires urgent action. It singles out industrial waste as having an adverse effect on the environment. It also recommends the adoption and implementation of cleaner production technologies as the answer to some of the problems associated with industrial waste.

3.7 Environmental management systems (EMS)
An environmental management system (EMS) is a documented set of procedures that identifies the impacts of a company on the environment and defines how they are managed on a daily basis. EMS programs which include ISO 9000, ISO 14001, ISO 18000 and ISO 22000. Environmental management system is a process of continual improvement with documented management and action plans. An eco-efficiency assessment identifies those areas of greatest impact and seeks to suggest financially attractive options to control or reduce these impacts [11]. An eco-efficiency assessment should not be undertaken separately from an EMS, instead it should complement it, with the outcomes of the assessment being incorporated into EMS action or audit plans.

3.8 Customer pressures
The voice of the customer is increasingly becoming a force to reckon with on environmental issues. Figure 1 shows that that companies can take a defensive attitude toward issues that are latent in society, but they do increase their focus when the issues matures in society. It is now an agreed fact that niche markets exist for green products. Business opportunities exist for products that require less energy and resources, generate less waste, or contained fewer regulated substances.

3.9 Food safety and HACCP
HACCP stands for Hazard Analysis Critical Control Point. It is an internationally recognized food safety standard commonly used in the food and beverage sector. The purpose of a HACCP program is to identify and manage steps in a processing operation that may pose a risk to food safety and quality. Proactive preventive procedures and controls are established to prevent or manage these risks [6]. It is essential that any eco-efficiency opportunities that are identified for a food company do not adversely affect food safety and quality. Water recycling is an example of an eco-efficiency opportunity where increased risk or perceived risk can be a barrier to its adoption. New procedures set in place as a result of an eco-efficiency assessment may need to be included and managed by the HACCP system. Conversely, a HACCP program may identify issues and link in with an eco-efficiency assessment.

3.10 Present use of eco-efficiency
Eco-efficiency is credited with encouraging the efficient use of resources. Two areas of eco-efficiency assessments are identified. The first tool is that as a measure performance at a system level eg process, product, company e.t.c. and as a tool to compare different alternatives (benchmarking) [6]. In both situations, the underlying motivation is to improve business performance.

3.11 How to carry out an Eco-efficiency project
The basic steps for carrying out an eco-efficiency assessment are presented below as stated in the eco-efficient toolkit for the dairy industry [7]:

- **PLAN** to put a program together.
- **MEASURE** to find out how much you use and how much you lose.
- **ASSESS** to work out what you can do to minimize losses and maximize gains.
- **IMPLEMENT** — starting with low-cost solutions to motivate everybody.
- **IMPROVE** by building continuous improvement and review into the program.
- **REPORT** to communicate progress against goals.

3.12 Eco-efficiency indicators
The common eco-efficient indicators or key performance indicators (KPIs) used in the food industry represent the resources consumed per unit of production. Typical key performance indicators for a beverage plant, for example, are shown in Table 1 below [12]:

Table 1: Typical Eco-Efficiency Indicators in the Food Industry

Product yield	kL product per kL raw material consumed
Water	kL consumed per kL product
Energy	kWh consumed per kL product, or MJ consumed per kL product
Wastewater	kL generated per kL product
Solid waste	kg generated per kL product

Indicators at the beverage plant can then be compared with benchmark figures. The development of benchmarks is an effective way to encourage continuous improvement within an industry. By comparing a plant's KPIs with those of similar processing plants, it may be possible to identify areas where there is scope for improvement.

4 ECO-EFFICINECY ENABLING TECHNOLOGIES

4.1 Technologies for minimizing water use

4.1.1 Boiler condensate return systems [9]
Water produced from the boiler system in the form of steam condensate can be recovered wherever possible, to reduce the amount of make-up water required by the boiler.

Fugure 1: Zim Beverages Co boiler in operation

Reducing condensate loss reduces water supply, chemical use and operating costs by up to 70%. A condensate return system also reduces energy costs, because the already hot condensate requires less energy to reheat. Steam traps, condensate pumps and lines are routinely inspected, while boiler systems should be maintained to reduce blow down and maintain boiler efficiency.

4.1.2 Re-design of a CIP system

A CIP system is one of the major sources of water consumption in a manufacturing plant. Traditional CIP systems are not efficient and use a lot of water than is necessary.

Figure 2: CIP station at Zim Beverages Co

A well-designed system minimizes the use of water and chemicals, and saves labour required for manual cleaning. CIP systems are usually custom designed for specific applications. At Zim Beverages Co, CIP system comprises of three tanks, which are for hot water, caustic and acid preparations.

4.1.3 Onsite water recycling and reuse

Zim Beverages Co has opportunities for recycling relatively clean water with minimal treatment. By modifying CIP equipment to include a recovery tank to store final rinse water, for example, it can recycle the water for subsequent pre-rinses. It may also be possible to reuse process water for other plant operations such as cleaning, cooling or boiler make-up water.

4.2 Toxic chemical use in beverage industry

Beverage and food companies use significant quantities and varieties of chemicals to:

- clean and sanitize food products and their packaging
- clean and sanitize plant and equipment
- treat water for washing, cleaning, sanitizing and processing
- treat boiler or cooling water.

Water treatment, cleaning and sanitation in food processing plants are essential factors in ensuring that food products do not become contaminated. The extent to which a plant treats its water, cleans and sanitizes is largely determined by food safety requirements, quality specifications and market expectations. Reducing chemical use *without* compromising processing or strict food safety standards can result in substantial savings, while also improving the firm's environmental performance.

4.2.1 Optimizing chemicals use in beverage industry

Cleaning and sanitizing programs in modern food plants are systematic procedures that include a series of steps, usually in the following order [6]:

1. **Dry cleaning** to remove most of the solid/semi-solid components and avoid adding them to the wastewater stream
2. **First rinse** to minimize the soid load in the cleaning system
3. **Detergent washes** to remove remaining soid through manual or mechanical scrubbing
4. **Second rinse** to prevent re-deposition of soid on the clean surface
5. **Sanitising** (this step is only required if there is direct contact with the product)
6. **Final rinse** to prepare equipment and surfaces for processing.

The most developed and widely used system used with chemicals in the beverage industry is the CIP system. CIP systems largely remove human contact with cleaning agents, thus reducing the risk of harmful exposure for staff. One of the main advantages of CIP systems is that they can re-circulate and allow the reuse of chemicals and rinse water; thereby reducing consumption by as much as 50%. The use of membrane filtration systems is becoming more financially viable, allowing greater recovery of water and chemicals.

4.2.2 Chemical alternatives

Non-toxic, biodegradable chemicals, such as plant-based cleaning agents, provides an opportunity to reduce maintenance and wastewater discharge costs while also contributing to a safer environment for employees. Some environmentally friendly cleaning products may be more expensive than traditional products, so it is important to take a holistic approach and consider some of the operational and downstream savings, and not just the initial purchase cost. Environmentally friendly chemicals are often perceived as not being as effective as conventional chemicals. Recent technological advances have made it possible to combine plant-based ingredients to create more powerful cleaning agents and natural disinfectants. For example, citrus oil extracted from orange peel (d-limonene) is being used to produce a natural petrochemical-free solvent and cleaning agent suitable for removing grease and fat. Examples of biodegradable chemicals finding acceptance in the food industry across the globe include [6]:

- Peroxyacetic acid is gaining acceptance in the food industry as a biodegradable and non-toxic sanitizing agent that is as effective as chlorine and can be used at low concentrations. In the fruit and vegetable industry, for example, peroxyacetic acid is being used for microbial control in flumes (conveying and washing product) and to wash product.
- Enzyme - based detergents - Enzyme - based detergents are finding acceptance in food industry applications for both foam-cleaning and CIP applications. Enzymes speed up specific chemical reactions in mild conditions of temperature and pH. The primary advantages of enzyme detergents are that they are environmentally friendly and non-corrosive and often require less energy input in the form of heat. Most enzyme cleaners are limited to unheated surfaces.
- Physical sanitizers- Physical sanitizing may be an alternative in some instances to chemical sanitizing. The former method of sanitizing involves the use of either hot water or steam. Typically hot water circulation is used, because it is easier to regulate. Chemical sanitation is more predominant in the food industry than physical

sanitation because the later requires more energy is required in the production of steam and or hot water.

4.3 Energy management

A good energy management program will identify uses of energy for a factory and highlight areas for improvement. One of the first steps in an energy management program is to find out where energy is being used across the site, which may require the installation of additional instrumentation such as steam, gas and electricity sub-meters [10]. Measuring and monitoring energy use will highlight opportunities for savings and in turn reduce greenhouse gas emissions. According to the same publication, the formation of an energy management team, involving a wide cross-section of staff, is a proven way of identifying opportunities to reduce energy consumption.

5. ECO-EFFICIENCY OPPORTUNITIES

Eco-efficiency opportunities can range from simple housekeeping improvements and minor process refinements through to major process changes or product redesign. The most significant eco-efficiency savings can often result from low-cost options such as improved housekeeping. Identifying opportunities involves rethinking conventional practices to come up with smarter solutions

5.2 Energy intensity reduction

These are some of the technologies that are adopted by an organization in reducing energy intensity at manufacturing plants to realize eco-efficiency improvements:

Solar energy

Solar energy can be used to produce power (via photovoltaic cells). An advantage of solar heating systems is that, although they can have high initial costs, operating costs are low if they are well designed and properly installed and maintained. Zim Beverages Co manufacturing plant has a large roof area space that can be utilized for solar collectors. Possible uses of solar heat energy are to pre-heat boiler feed water or hot water for cleaning.

Wind energy

Wind generators are a possible future source of alternative energy for companies located in areas that have a constant source of 'clean wind' . Wind energy concept is growing, with current generating capacity enough to provide power requirements for 83 000 homes. Wind energy costs about 7.5 cents/kW h to generate, and costs continue to fall at around 4%/yr as system are improved. Possible environmental constraints to using wind power include noise and effect on visual amenity.

Energy-efficient lighting [10]

Different styles of lighting are available for different purposes. They also have varying efficiencies. The following describes the different lighting types and their uses, from most to least energy-efficiency.

- **Low-pressure sodium:** This is the most efficient lamp type at present. It is most suited to exterior lighting and emits yellow light. Color is not discernible using these lights.
- **High-pressure sodium:** These are not as energy-efficient as low-pressure sodium lights. They are suitable for internal and external use, where color rendition is not important.
- **Metal halide and mercury vapor:** These are commonly used for high-bay factory lighting, and emit a bluish-white light. Metal halide is 25% more efficient than mercury vapor lighting. Two types of metal halide lighting are available — standard and pulse start. Pulse start lights are more efficient and start more quickly.
- **Fluorescent:** These are the most efficient type for lighting small areas with low ceilings, or for task level lighting. Fluorescent lights are available as a standard long lamp or in a compact style, which can be used as a direct replacement for incandescent lamps. The initial cost is higher, but the lamps use one-fifth the electricity and last up to 10 times as long. Standard 40 W fluorescent tubes can be replaced with 36 W high-density tri-phosphor tube, which are 20% more efficient and produce 15% more light.
- **Tungsten halogen lamps:** 240 V lamps are cheap to purchase but have high operating costs. They are useful for floodlighting.
- **Miniature di-chroic down lights:** These are often used in reception areas and restaurants. Their energy efficiency is inferior to that of fluorescent lights and they should be avoided if energy consumption is a priority.
- **Incandescent lamps:** These are the least efficient, and although they have a low purchase cost they will end up costing more in the long run because of higher operating costs and lower product life.

6. ZIM BEVERAGES CO. ECO-EFFICIENCY ASSESSMENT

The Figure 3 below shows the procedure that is followed when implementing a eco-efficiency assessment:

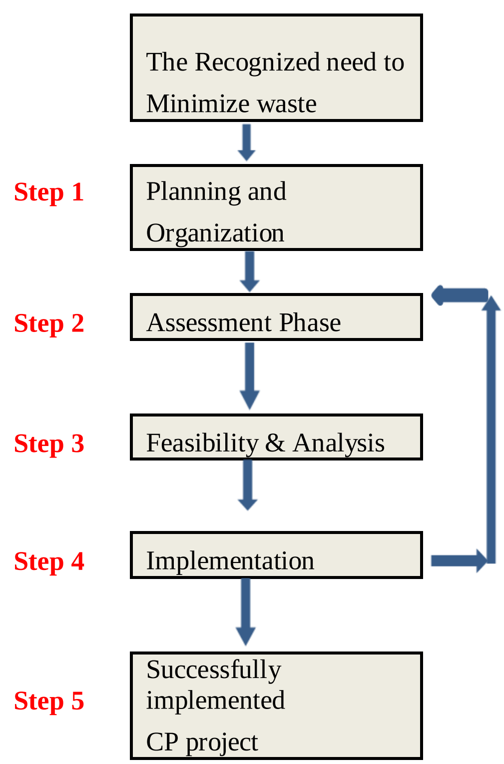

Figure 3: Eco-efficiency assessment procedures [2]

Flow chart as indicated in Figure 3 focusing on areas where products, wastes and emission are generated.

6.1 Pre-assessment activities

A checklist was then developed that would be used during the actual audit. Meetings were held with the team selected to agree on the roles of each member with the team. A senior management representative was included in the meeting so that team members would take the meetings seriously. Other issues looked at during the meeting included:

- ✓ Problems that could likely be encountered during the audit and mitigating measures if available
- ✓ Identifying all materials that would be needed during the real audit.
- ✓ Making sure all audit team members understood the procedures that were to be used.
- ✓ Developing a table for recording all waste streams during the audit.

6.2 Site investigation

The site investigation was in the form of a walk-through inspection to identify areas for improvement, particularly in housekeeping. The walk-through first covered the entire plant, and the focus then shifted to the specific problem areas noted during the walkabout. Some of the other issues that the walkabout sought to figure out included, obvious signs of waste, such as product that may have fallen from conveyor lines, leaking pipes and valves, accumulation of defective product and rework, steam leaks, excessively wet processing areas, spills etc. The team also took the chance to converse with the Zim Beverages Co operators and other staff to get a picture of what is happening in the work area and what some of the problems may be and for how long any identified situation has been going on for.

6.3 Assessment

On the assessment, quantitative data on all inputs and outputs were collected. Baseline data used was a one full year of operation of 2012, to get a good representation of electricity, coal, water use and toxic generation. An energy audit and water audit was conducted. Electricity and water bills were reviewed to get an insight of what exactly the company was paying for in the year under review. A measure of the plant's resource use and waste generation was determined. The information gathered was then used can be used to develop performance indicators that were used to identify inefficiencies, set goals for future work and evaluate improvements.

6.3.1 Energy Audit

As mentioned earlier on, an energy audit was conducted in order for the author to identify major energy-consuming equipment or processes. Under the energy audit, the following activities were done:

- The major forms of energy used at Zim Beverages Co by the processing plant
- A plot of annual and seasonal consumption patterns will be on a chart
- Break down energy consumption by section or equipment
- Identification of opportunities for energy savings.

The energy audit covered an in-depth study of all the major energy consuming equipment / stages of manufacture. The audit involved carrying out various measurements and analysis covering all major energy consuming sections, to realistically assess losses and potential for energy savings. The study focused on improving energy use efficiency and identifying energy saving opportunities at various equipment and processes. The analyses included simple payback calculations where investments are required to be made to implement recommendations, to establish their economic viability. A wide array of latest, sophisticated, portable, diagnostic and measuring instruments were used to support the energy audit investigations and analyses. The specialized instruments that were used during the energy audit included:

- Power Analysers
- Pitot tube & Digital manometer
- Fluke-41B-Power
- Fyrite Kit
- Anemometer
- Thermocouples
- Multifunction Kit
- Lux Meter
- Ultrasonic Flow Meter
- Digital Anemometer

During the audit, there was continuous interaction between the audit team and plant personnel to allow for possible concurrent implementation and to ensure that the suggestions made are realistic, practical and implementable.

6.3.2 Water audit

In the quest of understanding how Zim Beverages Co could manage its water resource effectively, the researcher deemed it essential to understand how much water enters and leaves the plant and where it is being used. This understanding helped a lot in singling out areas with the greatest opportunities for cost savings. The following methods were used in quantifying water use:

- Flow meters were used to measure water use directly.
- Where there were no flow meters, a bucket and stopwatch were used to estimate flow from pipes or hoses.
- Equipment manuals were used to estimate water use for some equipment, such as tanks and comparison was done with the actual water use.

6.4 Identifying root causes and generating solutions

Defective product may result from a culmination of individual problems upstream of a packing line, or excessive water may be used because of a combination of plant leaks, poor process control and low staff awareness. The following section describes tools that were used to identify the root causes of problems and how to solve them. Involvement of several knowledgeable personnel from the plant and the administrative departments helped in ensuring that all avenues are considered and that the potential solution does not create unintended problems in other areas. The root causes were analyzed using a cause-and-effect diagram, also known as a fishbone diagram. Root cause analysis allows a team of investigators to consider all possible causes of a certain problem, which may be people, procedures, technology or materials. The problem to be solved is written at the 'head' of the fish diagram. Members of the team suggest potential causes, which are written under the appropriate heading and make up the 'frame' of the diagram.

6.5 Evaluation and feasibility

The eco-efficiency opportunities identified will undergo two evaluation stages to determine their feasibility and practicality based on the impact of the change or solution on product quality, safety, customer expectations and environmental performance. At this stage, the economic and technical advantages of the eco-efficiency opportunity will be highlighted. It will highlight how much resources we will be able to save annually, and the associated cost saving. In addition, the payback period for each opportunity will also be estimated.

7. OVERVIEW OF ZIM BEVERAGES CO.

Zim Beverages Co manufactures non-alcoholic beverages. The domestic non-alcoholic beverages segment of the commercial beverages industry is becoming highly competitive in the backdrop of increased competition from regional players. Zim Beverages Co is in a drive to reduce operating costs and improving profitability. The energy costs are high and the company spends about US$ 30 000 on electricity. In the period January- December, 2012, the company incurred an average monthly expenditure of $14,300 in wastewater treatment and/or disposal costs. It is mandatory for the company to create an 'environmentally friendly' image and gain competitive edge as well as improve its relations with environmental regulators. It is also developing a waste minimization initiatives. The researcher reviews the energy, water intensity of the company and identify the major water and energy consuming activities or equipment at the company. Further, an eco efficiency assessment is done to determine the current eco efficiency improvement opportunities available for the company. Possible cost savings and related benefits of Cleaner Production Zim Beverages are highlighted.

Figure 4: Part of the Zim Beverages Co production line

Zim Beverages Co product lines include sparkling beverages; various water products, including packaged water; juices and nectars; fruit drinks and dilutables (including syrups drinks). Thus company faces both local and regional competition it hasto improve its current level of plant efficiencies to remain in business. Competitive factors impacting on the company business, include pricing, advertising, sales promotion programs, increased efficiency in production techniques, the introduction of new packaging, new vending and dispensing equipment, and brand and trademark development and protection.

7.2: Process Description

Below is the process flow chart of Zim Beverages Co:

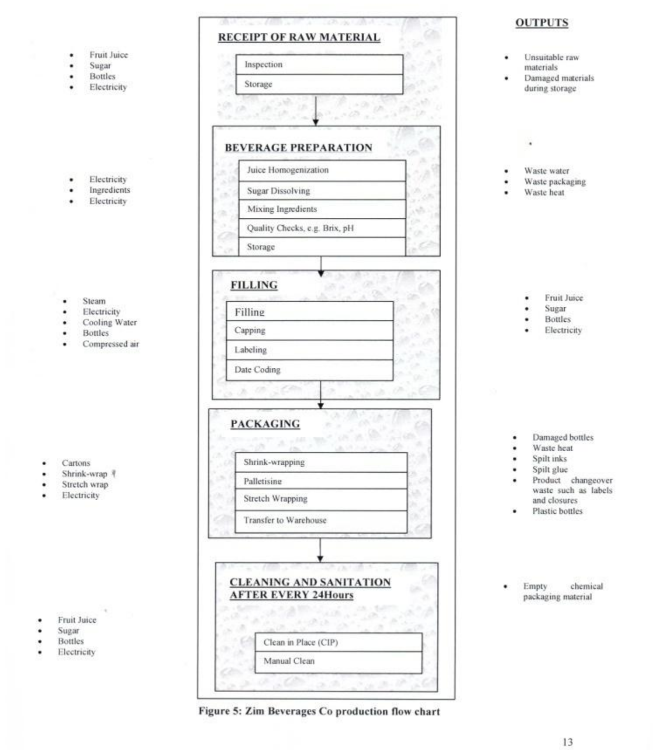

Figure 5: Zim Beverages Co production flow chart

This modern beverage processing plant consists of two main units which the actual beverage processing plant and the Poly-ethylenetetraphtalate (PET) manufacturing division for plastic containers. The plant is capable of producing the following products:

- Fruit Brand Products 40 hectoliters per year.
- Still water 5 hectoliters per year
- Ready to Drink Cordials 3.5 hectoliters per year

Figure 6: Product spillages during production

The filling machine was observed to run most of the time with product spilling to the drain as shown in the Figure 6 above.

Figure 7: Final rinse water being dumped into the drain

The final rinse water during the CIP is channeled to the drain yet it is relatively clean.

Figure 8: Bottle rinse water being channeled to the drain

Figure 8 above shows water from bottle rinsing that is being pushed into the drain and not being reclaimed.

Figure 9: Hose left running during lunch break on the filler line

The water coming out of the hose above was left running on the filling machine unattended. The hose is used for cleaning and lubricating the filler stars during running. It is undesirable for product to be left for too long without being cleaned form the stars as this will cause jamming of bottles during filling.

Figure 10: Unnecessary lighting during the day

On the production floor and several offices, lights are left "ON" even during the daytime, where they may be adequate daylight.

7.3 Major resource consumption

Table 2 below shows the resource consumption at the company for the year 2012.

Table 2: Resource Consumption for the year

Resource	Quantity used	Unit Cost ($)
Fruit Juice	2,056,030 Litres	2.38 per litre
Plastic Resin	1,249 Tonnes	2.10 per kg
Sugar	15,490 Tonnes	0.99 per kg
Coal	147,5 Tonnes	0.15 per kg

7.4 Key performance indicators

Table 3: Key performance indicators

	CURRENT PERFORMANCE (per liter of beverage)	TARGET PERFORMANCE (per liter of beverage)
INPUTS		
Water	2litre	1.5litre
Electricity	0.4MJ	0.3MJ
Coal	Unknown	Unknown
OUTPUTS		
Solid Waste	3.45g	3.0g
Wastewater Volume	0.53Litre	0.3Litre
Wastewater quality	Unknown	Unknown

The current and target key performance indicators of the company shown in Table 3 above.

7.5 Annual usage and cost of water

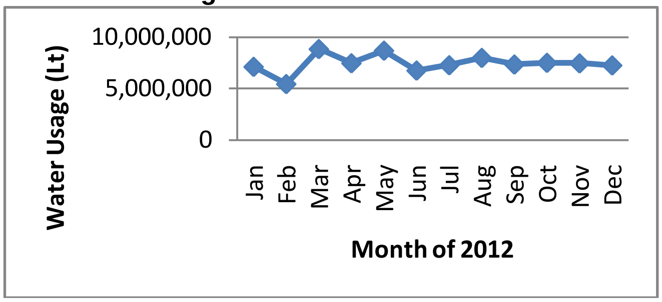

Figure 11: Annual water usage at Zim Beverages Co

Figure 11 above shows the 2012 water consumption trends at the plant. On average the monthly water usage ranges from about 5Million litres to 9 Million litres. For the year under review, there appears to be a stabilization of the water usage towards the end of the year to a figure just above 7 Million litres per month.

7.5.1 Breakdown of water consumption

Table 4: Water consumption by section

WATER USE PER PROCESS	Used Volume of water used annually (Litres)	% of total consumed
Product water	49,987,874	51.8
Water treatment	3,000,000	3.1
Package rinsing	3,600,000	3.7
CIP	16,000,000	16.6
Others, incl. general cleaning	2,000,000	2.1
Vehicle Wash Bay	500,000	0.5
Conveyor lubrication	50,000	0.1
Cooling water	100,000	0.1
Boiler feed water	100,000	0.1
Sanitary	2,000,000	2.1
Total	77,337,874	80
Actual Volume from Municipal source	**96,509,545**	100
Unaccounted	19,171,671	19.9

The greatest use of water at Zim Beverages Co plant is product preparation which accounts for more than 50 percent of the incoming water at the plant. 17 percent of the water at the company is used for equipment cleaning through the CIP system. The Clean-in-place (CIP) system is used in the plant for cleaning tanks, piping, filling machines, pasteurizers, homogenizers and other items of equipment. Of worry is the fact that 20 percent of the water that is received form the main municipal supply cannot be accounted for. The comparison of water usage at the plant versus production shows that production has a strong influence on water usage at the premises, which is a positive thing.

7.6 Energy used by the plant

The plant mostly use electricity and coal as the main forms of energy for the processes involved. Electricity is used for lighting, powering machines and for cooking, whilst coal is used for firing the boiler. The table below shows the quanties used for the year 2012.

Table 5: Energy Usage at Zim Beverages Co

Form of energy	Annual Usage	Annual Usage (GJ)	Annual Cost ($US)	% of total energy cost
Electricity	4857.70 MWh	17,488	382,933.10	97
Coal	81240kg	2,494	12,186.00	3
Liquid Petroleum Gas (LPG)	0.00	0	0.00	0
Solar	0.00	0	0.00	0

Table 5 shows clearly that electricity is the major form of energy used by the plant, as compared to coal. Figure 12 below shows that electricity consumption ranges from a figure of 300,000kWh to abour 500,000kWh in some month. It also shows that the lectricity consumption over the winter months of May to July was subdued, which may be explained by the fact that during that period, sales as well the production of the products are low as demand from customers is also low. The power demand generally is stable and this is attributable to the installation of a power factor correction unit in 2012. The monthly average electricity bill falls between US25,000 to US$ 37,000 per month.

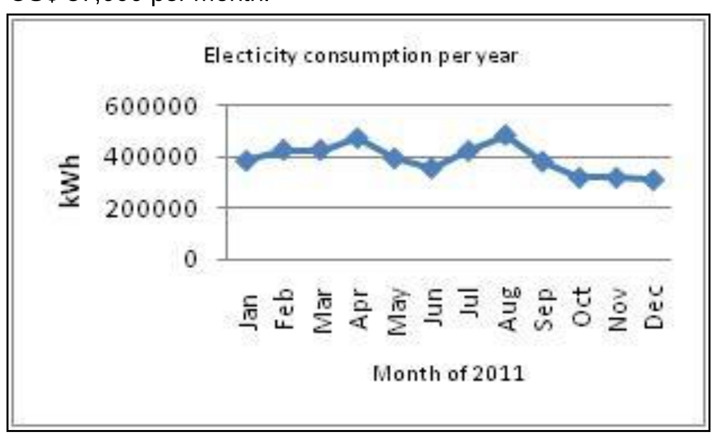

Figure12: Electricity consumption

7.6.1 Energy consumption by equipment

The 40-bar compressor is by far the largest single load at the premise contributing 34% to the electric load at the plant. The other loads are almost comparable, with an individual percentage load contribution averaging around 6%. For energy consumption of each piece of plant was determined to see how much each major load consumed in terms of electricity.

Table 6: Energy consuming equipment

Description of Load	Qty	Load (kW)	Capacity/Load	Hours of use per day	Number of days operation per Year	Estimated Consumption (kWh/year)	% of Total
Blow Moulding No1 Machine	1	34	80%	23	240	150,144	6.7
Blow Moulding No2 Machine	1	26	80%	23	240	114,816	5.1
Filling Line 2	1	22	80%	21	240	88,704	3.9
Filling Line 3	1	34	80%	21	240	137,088	6.1
Beverage Manufacturing Dept	1	25	80%	24	240	115,200	5.1
Staff Canteen	1	28	80%	12	240	64,512	2.9
40 Bar Compressor	1	157	95%	23	300	1,029,135	45.8
10 Bar Service Compressor	1	58	90%	24	300	375,840	16.7
Other	1	80	50%	12	360	172,800	7.7
Actual Electricity Consumed						**2,248,239**	**100.0**

The 40 bar compressor, stands out as the major consumer of electricity in the year under review.

Figure 13: The 40 bar air compressor in service

Of the major electric consumption of the plant, it was noted that the main contributing loads are in the form of electric motors. Electric motors are widely used in the plant in almost all the sections. Rating of motors varies from 0.5 kW to 250 kW based on the application, and the motors are rated at 380 V-400V at 50Hz. The major consumption of electricity by electric drives is in the following sections:

- 40 Bar Air Compressor
- 10 Bar Air Compressor
- Water treatment plant

7.6.2 Root cause analysis

For the high energy consumption of 0.4MW/litre against the best practice of 0.25MW/litre, the study developed possible causes of this high energy consumption using the ISHIKAWA method as shown below

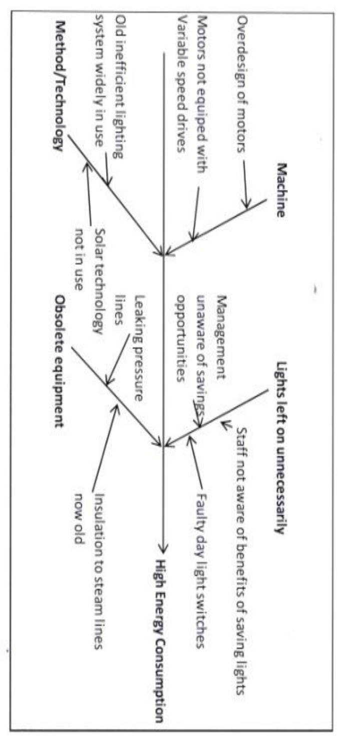

Figure 13: Root cause Analysis for high energy consumption

8 . ECO-EFFICIENCY OPPORTUNITIES

This section highlights the eco-efficiency opportunities identified by the study and presents the benefits that will accrue if the initiatives suggested are implemented.

Table 7: Opportunities for improvement

	Opportunities	Potential Resource saving		
		Water	Energy	Chemical
1	Optimising CIP system	✓	✓	✓
2	Install solar water heaters to the canteen		✓	
3	Re-routing of steam delivery system via a shorter path to the plant		✓	
4	Repair pressure Leaks on the 10 bar compressor Line		✓	
5	Recovery of backwash water at the water treatment plant	✓		✓
6	Replacement of Mercury lamps 400W with Metal Halide lamps 250		✓	

8.1 Technical and economic evaluation

In this section, the study evaluates the economic and technical advantages of implementing the eco-efficiency opportunities identified above.

✓ **Reclamation of final rinse water**

Background

During the survey, it was observed that final rinse water is not reclaimed on all final rinsing steps done. In a day, it was estimated that up to 7000 litres of water is used for final rinsing of product preparation tanks and pipes at the plant. For a plant operating an average of 240days per year, this figure translates to 1,680,000 litres that could be re-used at the plant.

✓ **Optimising Steam distribution Lines**

Background

The researcher and the investigating team with the help of external experts observed that, boiler is loaded 70% of its rated capacity for initial period of 2 hours and next 2 or 3 hours it is less than 50% of capacity. The initial period steam consumption is high for charging of lines. Because of some plant upgrade that was done several years ago, the route of the steam distribution network now spans to about 200metres between the boiler house and the point of use the point of use, yet the distance between Plant and the boiler house can be reduced to 50metres. Since the boiler only operates to a maximum of ten hours per day, steam (converted into water) accumulation is taking place in lines. There are no steam traps in place in the steam distribution lines to purge out the accumulated water. Before each time start-up of boiler saturated steam/water of previous cycle need to be flashed out to maintain high temperature steam for the final production department use. It is recommended to lay new steam line in shortest path to syrup section (in 50 m) instead of using present lines (compressor room – blow room- filling lines – top of lab). It avoids longer star-up period. Drawing of new steam line reduces operating hours of boiler by minimum 2-3 hours in a day. It is also recommended to install steam traps and strainers in new proposed main steam line. Optimizing boiler running hours will result into coal savings of 50 kg per hour.

Energy Savings

Estimated Average reduction in coal consumption: ~ 50 kg/hr
Reduced boiler operating hours per day : 2hrs (after new steam line in shortest path)
Annual reduced operating hours : 600
Reduction in coal consumption : 30 MT per annum
Cost of coal per MT : USD 176
Annual coal cost savings : USD 5280
Investment for new steam piping (50m) : USD 15,000
Simple payback period : 2.8 years

✓ **Install solar water heaters to the canteen**

Background:

It was observed that geyser capacity of 100 litres with 3kW heater coil is installed at the canteen area. Hot water is used for dish/plate washing after lunch and dinner. Below are the savings that may be realized if the eco-efficiency action plan above is implemented for the canteen. The existing units will remain as back-up during cloudy days.

Energy Savings

Annual Energy savings : 6240kWh
Annual Cost Savings : USD 561.00
@ USD 0.090/kWh)
Investment Cost : USD 2000
Simple payback period : 3.5 years

✓ **Repair Steam Leaks on the 10 bar compressor Line**

Background

A no-load test for the compressed air section is carried out for the 10 bar compressor during the weekend. The 10 bar compressor is designed with a free air delivery of 555 m^3 as per name plate details. The motor is Compressor motor is rated – 55 kW. When the load was actually measured, it was determined that the load power was at the maximum. With the air delivery of the compressor at 455m^3, the specific energy consumption of the compressor was determined at 0.12 kW/ (m^3/hr**).**

Results

Loading time (T) : 11 sec
Unloading time (t) : 13 sec
% leakage in the system : {T / (T+t)} X 00: 45.8
Leakage quantity : 208 m^3/hr

The evaluated compressed air leakage in the system is around 46% as compared to the design parameters of the compressor. The air leakage causes a pressure drop between the supply and end user equipment of approximately 2 bars. Compressed air leakage is nothing but waste of energy, in present case it is close to 46%. For this type of industry only a 5% leakage is acceptable. The walkabout identified that continuous air leakage is prevalent on all the pipes distributing pressure to all the packaging lines. An opportunity exists for the company to save energy and depreciation of the compressor by arresting air leaks on the piping network. After arresting the air leakage, loading time of the compressor is anticipated to be much lower than the present scenario.

Energy savings

Table 8: Compressor leakage savings

Parameters Values	Values	
Present energy consumption per hour, kWh	53	kwh
Designed Free Air Delivery for compressor	555	M
Evaluated leakage percentage	45.8	%
Leakage quantity,	208	m3/hr
Equivalent energy loss (208 X 0.12)	24.96	kWh
After arresting leakage no load power consumption	7.5	kWh
Net energy savings, kWh (Allowing 5% losses)	14	kWh
Estimated annual energy savings, kWh (operating hours 7200)	100800	kWh
Estimated cost savings, USD (Energy Cost USD 0.09 /kWh)	9072	$
Approximate Investment, USD	500	$
Simple payback period, years Immediate	0.1	Years

- ✓ **Replacement of Mercury lamps 400W with Metal halide lamps 250W.**

Background

At present some places in the plant, for high bay application Mercury lamps 400W and Metal halide 400W are used. Mercury vapor lamps are not energy efficient i.e. the efficacy (lumens/watt) of MV lamps is very low (45-55) compared to HPSV (100-135) and MH (80-105) lamps. Though sodium vapor (HPSV) lamps have efficacy than metal halide (MH) lamps, the color rendering effect of sodium vapor (HPSV) lamps is not good, as a MH lamp gives white light where as yellow light in HPSV lamps. Therefore, where color rendering is not important, in such places sodium vapor lamps can be used. A total number of 42-400 watt HPMV lamps may be replaced with 250 watt MH lamps as be identified.

Energy Saving

Table 9: Replacement of Mercury lamps with halide lamps

Description		Units
Number of 400 W mercury vapour lamps :	42	
Number of lamps for replacement of 400W HPMV lamps with 250W metal halide lamps	42	
Power saving per lamp	150	kW
Power saving from 42 lamps	6.3	kW
Hours of operation per year	7200	Hrs
Annual energy savings (considering 7200 hrs of operation)	45360	kWh
Annual energy cost savings @0.09USD/ kWh	4082.4	$
Implementation cost @ USD 46 / fitting for 250 W fittings	1932	$
Payback Period :	0.5	Years

- ✓ **Installing variable speed drive for the 40 bar Compressor**
- ✓ **Optimising the CIP system for it to re-use caustic**

Background

In the process of sanitization of the various tanks in the flow network 24 hours would easily see the cleaning of tanks occur 6 times. Based on either each tank individually or some repeatedly cleaned. In addition to the cleaning of the tanks and associated pipework additional large volume equipment is sanitised as well [mainly the two fillers]. The clean process is made up of five steps. A flush, rinse, chemical hold/circ, rinse … the amount of water used is based on circulation time and volume of plant item. The larger tanks typically use 1.2 m^3 with the smaller items 0.6 m^3. The target chemical percentage is 1-2% w/v. This means for every 100 litres of water 1 -2 kg of caustic flakes are required. This is tested in the larger for validation alkalinity strength test. After each clean the caustic and water is lost and dumped and in one day this can equate to up to 50 kg of caustic and 30 m^3 of water. To help reduce water usage and dumping of chemicals, reuse of the fluid can be achieve with adjustment of pipework. This would directly affect the 50 kg of caustic and the 5 m^3 of water used to dissolve it. It is proposed that the pipework would circulate the chemical using the chemical preparation tank as the feed tank. The solution will be tested before each subsequent use to allow adjustment of strength. This has the potential to reduce caustic use by 54% [27kg and water by 11% [3.3m^3] per day. In addition the new system would reduce the amount of prep time therefore increasing utilization/plant availability. This translates to a saving of 950 000 litres of water annually. In terms of caustic, we will realise a saving of about 2.5 tonnes annually. The cost of caustic is approximately $1.20 per kg, thus the company stands to save about US$7,800 annually. The cost on implementing the change is estimated at about US$5000

✓ **Recovery of backwash water at the water treatment plant**

***Backgroun*d**

At the water treatment plant, it is estimated that during backwashing of carbon filters, 20,000 litres of water is channeled to the drain per day. This translates to 4,800,000 litres of water that is put into the drain each year. One may be tempted to think that the cost is the charge of water per litre bought from the municipal authority but this is on site treated water that has consumed chemicals, energy and labor. To treat a batch of 60 000 litres of water at the water treatment plant, the following chemicals are required:

- 1kg of Ferrous Sulphate (toxic)
- 2.6kg of Lime
- 1.5kg of hypochlorite

By investing in an additional 30,000 litre tank, the backwash water can be recovered for re-treatment or for use in toilets and other utilities such as in the vehicle wash bay, watering the lawns, e.t.c and minimize the amount of water received from city of Harare. The savings that accrue are as follows:

- 4,800,000 litres of water
- 80 kg of Ferrous Sulphate
- 208kg of Lime
- 120kg of Hypochlorite

Apart for savings highlighted above, there are some more savings which are difficult to quantify such as labor savings and energy in pumping the water.

9. RESEARCH RECOMMENDATIONS

Table 10 below shows the summary of the eco-efficiency opportunities that could be implemented at the company and how much the company stands to benefit in terms of financial and environmental performance. Most of the opportunities identified can be easily implemented and some of them have already been implemented.

Table 10: Eco-Efficiency Implementation Plan

Eco-Efficiency Opportunity	Capital Cost	Annual Saving (resources)	Annual Saving ($)	Payback (Yrs)	Implement Date	Person Responsible
Optimising CIP system	$ 5,000.00	950,000 litres	7,800.00	0.64	3-Aug-12	Plant Engineer + Production Manager
Install solar water heaters to the canteen	$ 2,000.00	6240kWh of electricity	561.00	3.57		Plant Engineer + Production Manager
Re-routing of steam delivery system via a shorter path to the plant	$ 15,000.00	30 tonnes of coal	5,280.00	2.84		Plant Engineer + Production Manager
Repair Steam Leaks on the 10 bar compressor Line	$ 2,500.00	100,080 KWh electricity	9,072.00	0.28		Plant Engineer + Production Manager
Recovery of backwash water at the water treatment plant	$ 1,000.00	4800000 Litres of water + 0.4 tonnes worth of toxic chemicals	3,000.00	0.33	Immediate	Plant Engineer + Production Manager
Replacement of Mercury lamps 400W with Metal Halide lamps 250	$ 1,932.00	45360KWh of electricity	4,082.00	0.47	20-Feb-12	Plant Engineer + Procurement Officer
TOTAL	**$ 27,432.00**		**29,795.00**	0.92		

It is hoped that after the full implementation of the caustic use optimisation project, the water usage ratio will conform to the target water usage ratio of 1.5litre/litre of beverage consistently.

10. CONCLUSION

With only a few of eco-efficiency opportunities implemented, there is room for even greater savings such that there is a possibility that achievements may be one day used as the best practice standards. The several opportunities described and recommended in this study are not new, and could be considered as good operating or engineering practice; and they have been undertaken to some degree by some of leading world class companies around the world. Companies can start the implementation of eco-efficiency projects by riding on the success of their Environmental management systems. Environmental Management Systems can provide an important framework for eco-efficiency, as they supply a structure for setting targets, clarifying responsibilities, training, and raising awareness to achieve environmental improvement. For new industries that are starting up, it might be a good idea to ideally, adopt the best-practice technologies, procedures and initiatives should be considered during the design and planning stages of a plant which will maximize the benefits of eco-efficiency. A holistic approach should also be taken in deciding what is the most appropriate technology or plant design

11. FURTHER RESEARCH

Following from the research work undertaken further study can be done to investigate cost effective energy management options that Zim Beverages Co can pursue to realize savings on energy. Options like use of renewable energy, sub-metering of power, use of energy saver bulbs, and use of now available pre-paid meters from the power utility company can be viable options as eco-efficiency power cutting initiatives for the future.

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