A COST BENEFIT ANALYSIS OF WATER RECYCLING IN MANUFACTURING INDUSTRIES: A CASE STUDY OF THE EAST AFRICAN BREWERIES LIMITED, KENYA

BY

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Z50/75005/2014

A Thesis submitted in partial fulfillment for the Degree of Master of Arts Environmental Policy in the University of Nairobi

October 2016

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

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Supervisors Declaration

This thesis has been submitted for examination with our approval as University supervisors at the Centre for Advanced Studies in Environmental Law and Policy (CASELAP), University of Nairobi.

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DEDICATION

I dedicate this work to my beloved mother who has inspired me throughout my academic and professional journey.

ACKNOWLEDGEMENTS

I take this chance to appreciate my supervisors for their guidance that aided the completion of this dissertation. I also wish to appreciate the support of the Centre for Advanced Studies in Environmental Law and Policy's (CASELAP), it's teaching and non-teaching staff for making this study a success, especially Prof Nicolas Oguge and Dr. Elvin Nyukuri and my classmates for their input during the study. Special thanks goes to my father Fred Wakhungu and Terry Ngugi for their constant contributions towards this study. Lastly, I thank the Key informants who cooperated with me during the data collection exercise and the East African Breweries Limited for allowing me to undertake the study in their premises.

ABSTRACT

Water recycling offers a potential solution for water scarcity and way for manufacturing industries save on water purchases and wastewater disposal. This is true for large water consumer like East African Breweries Limited (EABL), whose operations are highly dependent on reliable water supply. While water recycling has become a popular concept, little information exists on the costs and benefits of industrial water recycling and the reasons for the reluctance in its adoption. Similarly, Kenya's policy and regulations on water recycling are still not widely understood. The aims of this study goal were to compare the costs of treating and recycling water in at EABL to its benefits, shed new light on challenges in greywater recycling at EABL, and evaluate Kenya's regulatory framework on water recycling in the manufacturing sector. This case study carried out between March and July 2016 used both qualitative and quantitative data from primary and secondary sources collected through key informant interviews and literature review. The avoided cost method was used to determine the benefits, while the costs were obtained through data from key informants. The Net Present Values (NPV), benefit cost ratio (BCR) and Internal Rate of return (IRR) were tests used to assess the viability of water recycling at the brewery. The analysis of the data from the interviews and literature review informed the assessment of the challenges and Kenya's regulatory framework industrial water recycling. Results indicated that greywater recycling was economically viable. In fact, the avoided costs by EABL were US$ 241.90 Million, US$ 604.79 Million and US$ 743.06 Million for recycling 10%, 25% and 50% of the water consumed annually respectively. This represented a return of US$ 3.11, US$ 3.65 and US$ 4.01 per invested dollar for 10%, 25% and 50% recycling, respectively according to the Benefit Cost Ratio (BCR). According to the IRR test, all the recycling capacities were viable regardless of inflation rates. The study also revealed that the high cost of water recycling technologies and lack of incentives were the biggest the challenges that hinder industrial water recycling. Surprisingly, the study found that water recycling was inadequately addressed in water related regulations and there was no institution with the mandate of spearheading water recycling in the manufacturing and domestic sector. In addition, Kenya's regulatory framework leaned towards control of effluent rather than the reduction of wastewater production and promotion of water recycling. The conclusion was that water recycling at EABL was economically feasible for all capacities evaluated in the study. There was need to address these challenges through the reform of the regulatory framework, allocating water recycling responsibility to an institution and awareness creation to improve acceptable of recycled water

LIST OF ACRONYMS AND ABBREVIATIONS

BCR	Benefit Cost Ratio
CBA	Cost Benefits Analysis
EABL	East African Breweries Limited
MENR	Ministry of Environment and Natural Resources
NCWSC	Nairobi City Water and Sewage Company
NEMA	National Environment Management Authority
US EPA	United State Environmental Protection Agency
USD	United States Dollars
WRMA	Water Resource Management Authority
SDG	Sustainable Development Goals

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CHAPTER 1: INTRODUCTION

This section of the report begins with a brief overview of foundational information related to this study, followed by a discussion of the problem, statement of the research question and objectives, as well as the description of the importance and limitations of this study.

1.1 Background of the Study

Water scarcity is a real global problem occasioned by population and industrial growth as well as climate change. According to the United Nations, (2016), water scarcity affects more than 40 percent of people around the world, a figure projected to increase. The prolonged droughts have further affected worsened the situation. As a result, many countries have embarked on grey water recycling as a sustainable and alternative source of potable water (United Nations, 2016). In fact, SDG 6 strongly recommends the support of water treatment technologies and countries like Australia, United Kingdom, Canada and the United States of America have upscaled water recycling.

Population growth is the principal driver of the global demand and Bigas (2012) expected the global water demand to grow by 30 percent between 2000 and 2025, and by as much as 50 percent between 2000 and 2050. Of the 33 percent of nations that had suffered from water scarcity as of 2006, many were in Sub-Saharan Africa (UNECA, 2012). Weighed against the rapid population and the economic growth recently recorded in these countries, questions can be asked whether they will have sufficient water to meet their social, economic and environmental needs.

At the country level, the latest World Bank Group (2016) economic analysis for Kenya projected a continued growth in infrastructure, agricultural production, and expansion in manufacturing industries. This puts Kenya among the fastest-growing economies in East Africa. This population and economic growth has subsequently caused a widening gap between demand and supply over time as witnessed in Nairobi city (Pravettoni, 2011). Because the manufacturing industry is among the growing economic sectors in Kenya according to the Kenya National Bureau of Statistics (2015), the subsequent effect is the increase in industrial water demand.

Since manufacturing industries need access to reliable, affordable, and quality water (Cosgrove, 2004), water recycling is a great opportunity to sustain operations, and increase profitability. In fact, "two-thirds of the world's largest companies are seeing benefits to their bottom line by switching to sustainable and effective water management (CDP, 2014). The United States Environmental Protection Agency (EPA) suggests that recycled water for non-contact applications is widely accepted after appropriate treatment processes for industrial uses like cooling, and material washing or nonindustrial uses like landscape irrigation, and toilet flushing.

Based on records obtained from the Nairobi City Water and Sewerage Company (NCWSC), EABL is the largest consumer of water in Nairobi. Records show that from January to June 2015, it consumed 409,400 units at the cost of US$ 390,269 and only followed by Nairobi Bottlers Limited with 320,840 units at US$ 305,808. Through appropriate treatment and reuse of wastewater for different purposes, EABL can cut down on its demand for water. This has been documented in brewing industries elsewhere.

In San Diego United States, Stone Brewery launched a beer made from recycled water in a ‘toilet to tap’ program which is still at the experimental stage (Daley, 2017). Another example can be found in Australia, Castlemaine Perkins Ltd, that produces beer at the Milton brewery adopted water recycling to comply with the Queensland Water Commission water restrictions. The plant consisted of the biological treatment technology, membrane systems, reverse osmosis chamber used to reduce salt content and a disinfection unit with ultraviolet light (Hertle *et al*, 2014).

Apart from water scarcity, another problem related to manufacturing processes is the increased wastewater due to the growth of the economy and demand for goods. This has increased pressure on wastewater infrastructures in cities. In Nairobi, all wastewater collected, is channeled to the Dandora and Kariobangi wastewater facilities, and the recently commissioned Ruai wastewater treatment in the eastern parts of the city. After primary and minimal secondary level treatment, the effluents are discharged to the river systems which flow through the city (Omwenga, 2010). The negative implications on the environmental, health, and social well-being of downstream ecosystems and communities can be reduced by water recycling cuts down the amount of wastewater released into the environment.

For the implementation of water-recycling projects in the manufacturing sector, feasibility studies are essential in comparing their benefits and costs. Management and policy decisions rely on using the Cost Benefit Analysis (CBA), a useful tool determine whether water recycling is a sound or justifiable investment (The Organisation for Economic Co-operation and Development, 2006). Besides that, a water recycling operates in a regulatory framework that stipulates the production and use of treated wastewater for municipal and industrial applications (Kellis, Kalavrouziotis, & Gikas, 2013). To stimulate water-recycling projects in manufacturing industries, such frameworks ought to be non-prohibitive.

1.2 Statement of the Problem

Water scarcity driven by the increasing demand for domestic and industrial water against dwindling supplies is a phenomenon in many parts of the world. As the consumption goes up, it also brings with it the challenges in wastewater management. As a result, the wave of green technologies such water treatment have gained prominence as a way to keep pace with the current demand and supply scenarios and solve the wastewater disposal conundrum. However, the uptake of the water technologies has been notably slow to make significant gains (Bigas, 2012).

For manufacturing industries like EABL that consume large volumes in their production as seen in the introduction section of this paper, the need to upscale water recycling is even bigger given the widening gap between the supply and demand in Nairobi. The World Wide Fund (2011) estimated the total water demand for Nairobi to be 650,000 units per day, while the supply stood at 482,940 units per day. Therefore, the inadequate and high prices of water for production will continue to affect the productivity and profitability of the manufacturing sector, particularly the high consuming entities like EABL.

From a sustainability standpoint, water recycling not only addresses the needs of the manufacturing industry but also reduces the consumption of water resources, and the negative effects of wastewater disposal on the social, and environmental domains. However, water recycling in the manufacturing sector is a scantily researched area. One of the neglected areas is the establishment of cost and benefits of industrial water recycling, yet it plays a critical role in determining the feasibility of water recycling as a solution to the current water scarcity and wastewater disposal challenges. In reality, the current publications on CBAs are limited to developed countries like Germany and Australia, but very little on Kenya.

Similarly, as industries look to join the wave of water recycling, there is an urgent need to remove any bottlenecks to ensure willing industries contribute to sustainable water use and wastewater disposal. Nevertheless, few studies have looked at the challenges that hinder the uptake of water recycling technologies in the manufacturing sector, specifically in the Kenyan context. Another fundamental area that appears to be ill defined yet it is important in the implementation of water recycling schemes is the regulatory framework, which consists of regulations, institutions. In fact, previous work has been limited to countries like Israel, USA, France, Tunisia, South Africa, UK, and Australia.

1.3 Research Questions

The following questions guided this study.

i. What are the costs and benefits of water recycling at the East Africa Breweries Limited?

ii. What are the challenges to implementation of a water-recycling scheme at the East African Breweries Limited?

iii. How has Kenya’s policy and regulatory framework addressed water recycling in the manufacturing?

1.4 Research Objectives

The following were the specific objectives for the study.

i. To examine the costs and benefits of water recycling at the East African Breweries Limited.
ii. To assess the challenges to implementation of a water recycling scheme at the East African Breweries Limited
iii. To evaluate Kenya’s policy and regulatory framework on water recycling in the manufacturing sector

1.5 Justification and Significance of the study

This study of water recycling in the manufacturing sector was undertaken for several of reasons. The most important factor was that while water recycling offers solutions to water problems and continues to trend on a global scale, little information exists on the cost and benefits of water recycling, its challenges and related laws and policies. This study is important and unique as it offers insights into industrial water recycling in the Kenyan context using EABL is one of the biggest Kenyan Brand.

Besides contributing to the existing body of knowledge on water recycling by looking at Kenya’s manufacturing sector, using EABL as a case study. It also offers baseline information for future research as it is the first study in the scarcely researched area of the cost and benefits of water recycling. The findings of this study are also important because they form a basis for decision-making at EABL on the levels of water recycling and the respective benefits brought by the options. It is useful for setting benchmarks and goals for water management and these are lessons can be passed to government agencies and other companies.

By discussing the challenges that hinder the adoption of water recycling in the manufacturing sector, and state of Kenya's regulatory framework on water recycling, this study informs future conversation for policy makers on what strategies are needed to upscale water recycling in the manufacturing sector and policy reforms based on gaps identified. The finding of this assessment would inform focused interventions that would stimulate water recycling in the manufacturing sector.

1.6 Scope and limitation of the study

The study scope included a CBA of water recycling at EABL, assessment of the challenges to the implementation of a water-recycling scheme at EABL, and evaluation of Kenya's regulatory framework on industrial water recycling. First, this study was limited by time based on the timeline for research and presentation of the thesis by the institution. This limited the cost benefit analysis to the evaluation of economic benefits because determination of the social and environmental benefits required time and resources that were not available at the time of the study.

Secondly, the inadequate of data on water recycling in the manufacturing sector in Kenya, especially in breweries, was a challenge since literature review lays the foundation for the understanding of the thesis. Despite the existence of many studies related to water recycling, there was hardly any information on the cost and benefits of water recycling, the challenges that hinder adoption of water recycling technologies, and the regulatory framework for water recycling in the Kenyan context.

The use of interviews in data collection might have inhibited or limited the key informants in giving more information; therefore, future research should carefully consider the data collection to ensure as much information is gathered. On the other hand, the reliance on the key informant interviews limits the study as data may contain biases especially exaggeration when giving opinions. The over-reliance on the key informants' ability to recall facts that inform the study was also a challenge to the study.

Lastly, the shortcomings of the economic valuation approach used to estimate the costs and benefits of water recycling may have had an impact on the result. The use of the avoided cost method, a cost-based approach, in quantifying the benefits and costs was a limitation as some of the environmental goods or benefits do not have markets, and prices are hard to determine. Even in cases with an existing market, markets can be distorted by factors like monopolization (Kumar, 2010)

CHAPTER 2: LITERATURE REVIEW

This second chapter looks at literature that falls within the scope of this research and how they influenced the research problem, methodology, results, and conclusions. The discussions were organized based on the three research objectives discussed in section 1.4 of this paper.

2. 1 Cost and benefits of water recycling

The term water recycling refers to use wastewater from domestic, industrial or commercial sources after the removal of impurities; this is in accordance with Bischel, *et al*., (2013). Several authors including Levine & Asano (2004) have considered water recycling as an important cog in the balance of production processes and environmental sustainability. In their view, the beneficial uses of recycled water include landscape and agricultural irrigation, industrial cooling processes, general cleaning, and toilet flushing.

One way of examining the economic viability of a recycled water scheme is to consider the marginal value of the scheme using a CBA. The Australian, Department of Treasury and Finance (2013) considers it the most comprehensive economic appraisal technique, and the preferred method in resource economics and management. Surprisingly, relatively few studies have evaluated the costs and benefits of water recycling in the manufacturing sector.

In their work, Chougule & Sonaje (2013) did a CBA of a wastewater recycling plant for a textile industry. Their overall costs for the recycling plants included the construction of a cationic exchange resin, an anion exchange resin, a chloride treatment chamber, electricity, maintenance, depreciation costs, and staff salaries. For this plant, the benefits consisted of reduced expenditure on water and sale of water recycling by-products. While their efforts are plausible for laying the foundation for future work, their publication does not provide sufficient information about their CBA procedure and methods. It lacked an evaluation period, which is important in assessing the viability of the project over the period (Department of Treasury and Finance, 2013)

While not much exist on the cost and benefits of water recycling in the brewing sector, Lahnsteiner & Klegraf (2005) demonstrated that water recycling in breweries was possible in their publication on malt plant that used wastewater in barley marinating. While using the interest rate of 10% and for a period of 20 years, they found that the plant, consisting of a precipitation, sand filtration, pH-adjustment and chlorine dioxide chambers, achieved considerable savings by using recycled water for secondary purposes like cooling, irrigation, general cleaning and use in toilets. Although their case study was at a brewery in Germany, their study was very useful to this study at EABL because they provided a point of comparison.

Hertle *et al.*, (2014) conducted another CBA of water recycling at a brewery in Australia. They showed that through treating and reusing a 2.2ML per day, the plant lowered water purchase, and payment for sewerage discharge at the rate of US $ 4.2 Million per year. This represented a payback of 5 years. This treatment scheme consisted of a screening chamber, a balance tank, a sequencing batch reactor, microfiltration membranes, a reverse osmosis chamber and a disinfection unit. Their valuable contribution to this study was that they offered a comparison tool for the benefits of water recycling at EABL, but omitted important information such the discounting rate and evaluation period.

These studies by Chougule & Sonaje (2013); Hertle *et al* (2014); Pickering (2013) and Lahnsteiner & Klegraf (2005) lay a foundation for a CBA at EABL. They listed capital costs for a treatment plant as design, construction, and land acquisition while the recurring costs included treatment materials, administration human resources, maintenance, and repairs. More importantly, the justification given by Kumar (2010) for the use of the avoided cost approach as a way to establish economic benefits validated its future use in CBA undertakings.

However, the major pitfall for these studies was the ambuiguity of their methodology. The failure to perform sensitivity tests to evaluate the viability of their recycling projects under different interest rates or inflation regimes. Surprisingly, these studies did not have underlying theories, a gap that addressed by this study. To provide broader perspectives on the benefits and cost of water recycling in the manufacturing sector, this study detailed the methodologies, and undertook a CBA in a different context form these studies in this section.

2.2 Challenges in industrial water recycling

The section looks at the literature on the problem relating to the adoption and operation water recycling projects in manufacturing industries. From a general water quality and quantity perspective in food-related production processes, Kirby, Bartram, & Carr (2003) recognized that with the increasing water scarcity, water recycling remains a welcome option especially due to the large amounts of water required by the food industries. Notably, they further listed the varying water quality needs as a challenge to efforts to for universal uptake of the water reuse concept. While their assertions point to a single problem, other studies point to the existence many other challenges that ought to be understood.

Work carried out by Casani & Knochel (2002) acknowledged the rise of water recycling in the food industry partly due to the increasing cost of water and discharge. In this study, they identified the risks of microbial contamination as the biggest problem in water recycling in the manufacturing sector. They further proposed the elaborate evaluation of water recycling systems and implementation of an information model on food and water borne pathogens. This was important as provided insights on the key issues related to recycling water for the production of alcoholic beverages at EABL.

Similarly, work by Kularatne, Ridley, & Cameron (2005) was important to this study as they looked at look at how public perception affects recycled water use in the manufacturing sector. In their discussion, they cited health concerns and low acceptance of products from production lines using recycled water. This challenge attributed to the lack of public trust, unclear and inconsistent information as well as continuous miscommunication of recycled water.

In their discussion of strategies for implementing new recycling projects, Po, Kaercher, & Nancarrow (2003) reached the conclusion that the lack of clarity in water reuse regulations was a challenge to water recycling across all sectors. In their recommendation, their view was that only greater clarity and specificity in water recycling regulations could make them easier to interpret and stimulate implementation of water recycling projects. Their analysis provided a hypothesis for the evaluation of how regulations affect water recycling in the manufacturing sector in Kenya, more specifically at EABL.

Although there is a general agreement among many scholars including Casani & Knochel (2002); Hartley (2006); Kirby, Bartram, & Carr (2003); Kularatne, Ridley, & Cameron (2005) that there are many challenges in water recycling, the information gathered in their preliminary works remains fragmented. Like in the evaluation of the costs and benefits of water recycling, not much information is available on the challenges related to water recycling in breweries, especially in the Kenyan context.

2.3 Regulatory framework of water recycling

As proposed by Hamilton, *et al.*, (2005), streamlined regulations and clearer guidelines around standards could improve industry knowledge of the impact of water reuse. With the complexity of the water industry, they advocate for tailoring of general water recycling guidelines to a specific country and regional needs. Therefore, the water industry needs to build a bank of credible, robust data to demonstrate that reused water is safe and acceptable.

Plenty of information on regulations in water reuse exists, especially in the United Kingdom, Australia, and the USA. However, studies specifically evaluating the regulatory framework for water recycling are rare at the local level. In one of the few works, Onjala (2002) indicated that there are few water policy instruments in Kenya and a large portion of them remained unformulated. The existing are not specific to water recycling but relate to water quality started.

Casani, Rouhany, & Knochel (2005) considered regulations on water recycling to be a limitation to water recycling. They observed that some regulations by public health authorities were obstacles to implementation of water reuse schemes. They also cited Israel, USA, France, Tunisia, and South Africa as countries that have established strong and favourable guidelines and regulations for water recycling.

Further, Po, Kaercher, & Nancarrow (2003) believe that the disconnect in water management strategies is a policy gap that needs to be addressed. In the same publication, the authors recommend development of appropriate guidelines for water reuse that will work locally and integration of water reuse into the total water budget. Their view that water recycling policy strategies ideally consist of incentives, mandates, and regulations, removal of barriers as well as education and outreach. This observation was crucial to this study because it informed what formed a water recycling regulatory framework.

CHAPTER 3: METHODOLOGY

This chapter presents the theories, conceptual framework of the study, and the study site. It further and details the data types and sources, data collection methods, and the data analysis procedures used to achieve the three objectives set out in section 1.4 of this study.

3.1 Analytical Framework

This section consists of the theoretical framework which discusses the urban metabolism and sustainable development theories and how they support the study. It is followed by conceptual frameworks, that provides a general direction of the research and the relationship between the variables.

3.1.1 Theoretical Framework

The role of industrial water recycling in meeting industrial water demand and solving the problem of wastewater disposal can be illustrated by the urban metabolism theory. With its roots in sociology, it is “the analysis of the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy and elimination of waste”, Kennedy, Cuddihy, & Engel-Yan (2007).

It suggests that for material consuming entities like cities and industries, they receive material inputs from the environment and generate waste after metabolic processes (Pincetl, Bunje, & Holmes, 2012). For manufacturing industries like EABL to be self-sufficient, evaluation of material flows from the point of input to output is required. This then informs the alteration internal system processes to reduce wastes and the demand for inputs. Based on the urban metabolism theory, the study's thesis was that water recycling at EABL (illustrated in Figure 3.1) would reduce both water consumption and generation of wastewater by the brewery.

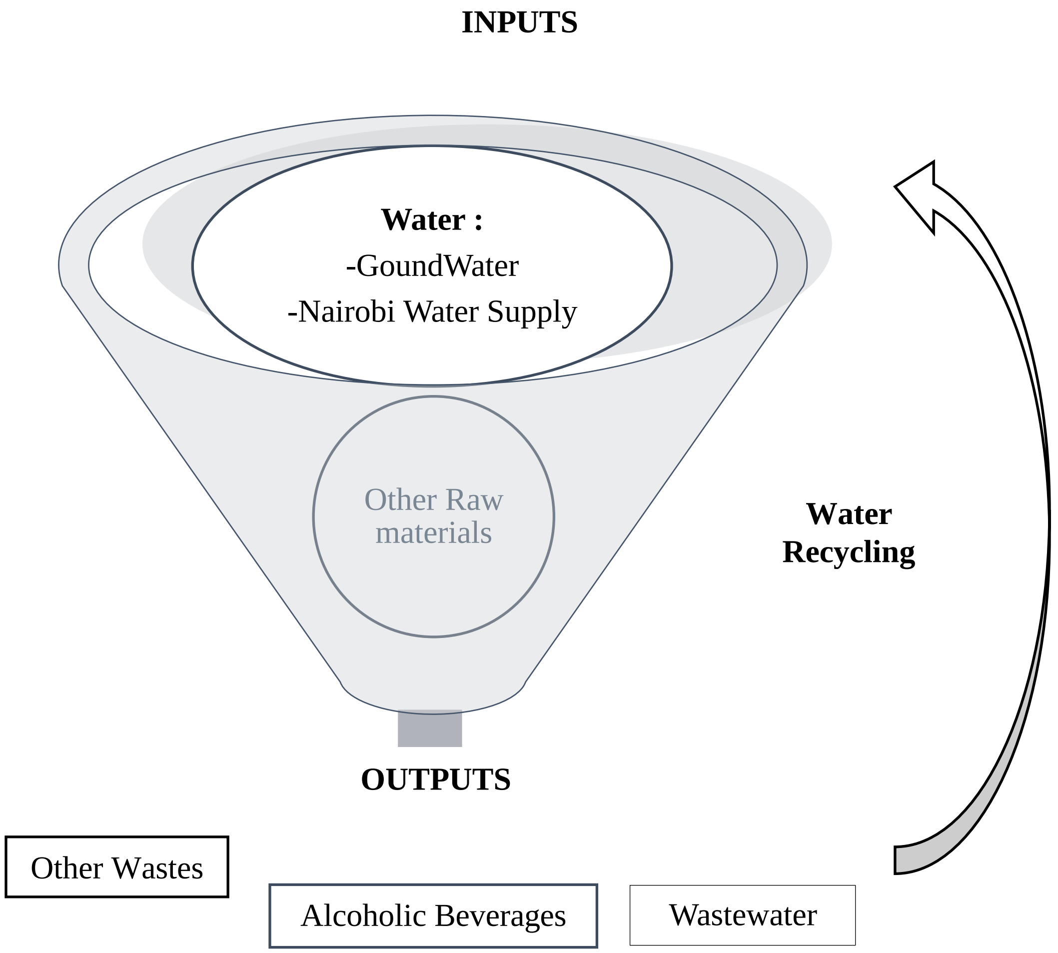

Figure 1.Water flow in the production process at EABL

Source: *Author*

Previously, studies have used it to assess the sustainability of socioeconomic processes in terms of material resources and energy. For example, Sun, et al., (2016) used it to evaluate the sustainable development levels and the driving forces of energy in Shenyang, northeast China. Based on their findings, they recommended investment in renewable energy and ecologically sound industrial developments.

These principles of the urban theory are embedded in Sustainable Development Model as espoused in the Agenda 21, a product of the 1992 Earth Summit in Rio De Janerio, Brazil. In line with Principle 8 that calls for the elimination of unsustainable production and consumption patterns, the contribution of EABL and other manufacturing industries would be in the reduction in water use and waste production. To achieve this, Principle 9 calls for the adoption of innovative technologies among them water recycling (United Nations, 1992). Whether in pursuit of environmental or economic sustainability, water recycling is an important cog in the discussions on self-sustenance at EABL or other manufacturing companies in Kenya.

3.1.2 Conceptual Framework

An efficient manufacturing system as envisioned by the urban metabolism theory is that which reduces water consumption and wastewater water production. These variables are illustrated in Figure (3.2). The first set of independent variable includes the high intake of water by industries, and overexploitation of water sources to meet the industrial water demand representing water consumption. The second set comprises of the cost of effluent discharge and the impact on the environment. The correlation between water consumption and effluent discharge is that in an industrial process, the water intake is proportional to effluent discharged. Similarly, the discharge of effluent in the environment affects the quantity of water available for industrial use.

As part of the study’s intervention, the intervening variables included a cost-benefit analysis, evaluation of challenges and regulatory framework on industrial water recycling. The expectations were that these would stimulate water recycling in the manufacturing sector and the indicators for these interventions would be reduced water consumption. These result in reduced expenditure on water, and reduction in water intake.

For Effluent discharge, the indicators were the cost savings on wastewater disposal, equivalent to the amount of wastewater that would have been released to the environment. In the long term, sustainable water consumption and effluent management contribute to the goal of sustainable manufacturing industries. The lessons learned from the process can be replicated in other sectors and inform policy improvement.

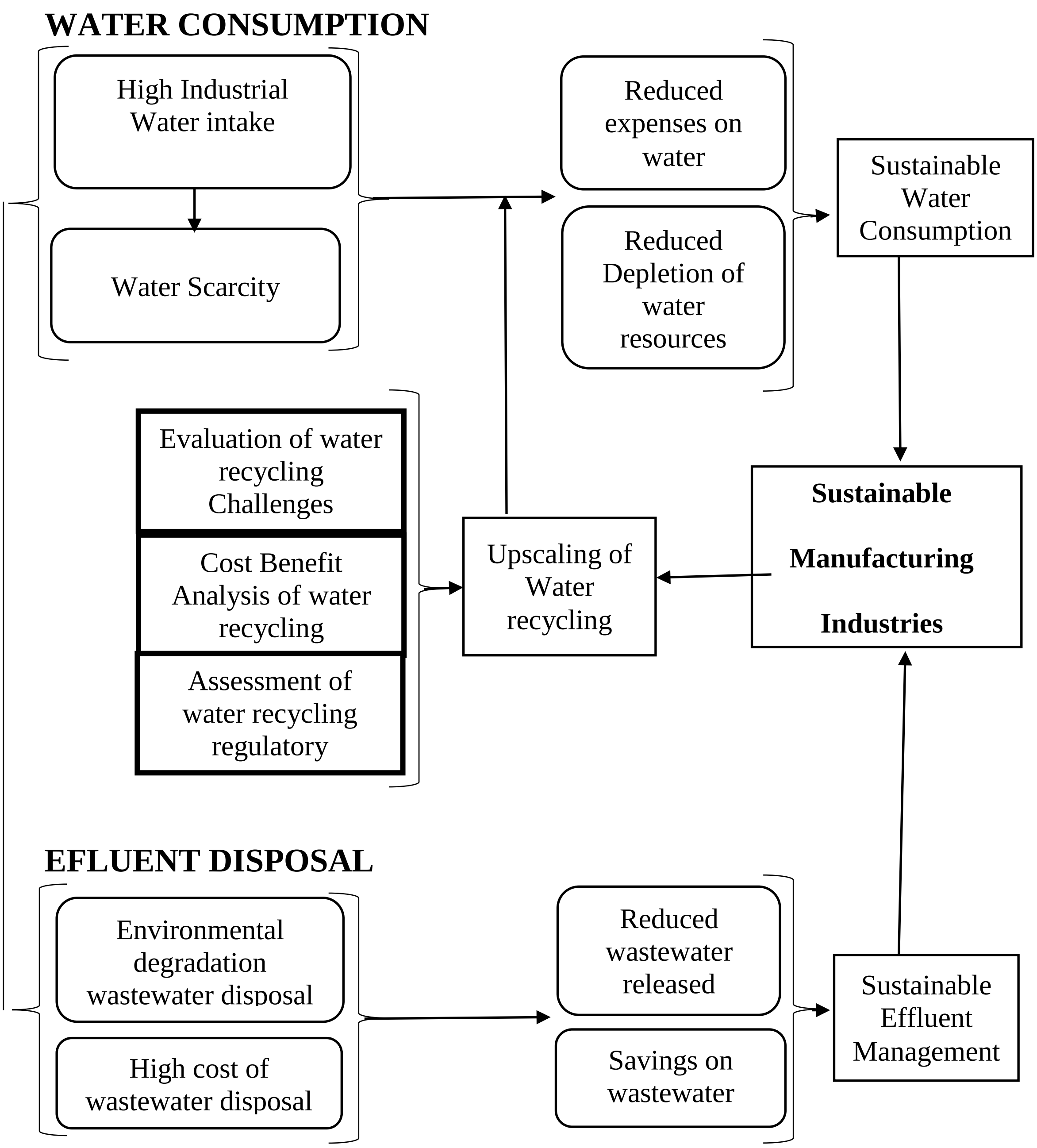

Figure 2. A Schematic illustration of the conceptual framework

Source: *Author*

3.2 Research Design

3.2.1 Study site

This case study was undertaken between March and July 2016 in Nairobi County at EABL, a Kenya-based holding company located off the Nairobi-Thika Superhighway. It is approximately 25 kilometers from the Nairobi Central business district in Ruaraka. EABL was chosen for this study because it is the single largest water consuming manufacturing company in Nairobi. As a result, recycling at this brewery would lead to huge savings in water and subsequently reduce wastewater discharge.

The Ruaraka plant, consisting of a brewery and distillery, produces beer and spirits distributed across the region. Since its establishment in 1922, and subsequent installation of a pasteurization plant in Ruaraka in 1924, the production grew tremendously. This made EABL East Africa's biggest alcohol beverages brand and the most respected company in terms of growth, company policies, and range of products (EABL, 2013)

EABL is keen on environmental sustainability. In 2008, the company launched the Green Goals 2010 initiative; an ambitious environmental program focused on reducing the company's carbon footprint. The program involved reduction of energy usage at the plant to prevent pollution, minimize the environmental impact of all products and operations. Additionally, the company's Water of Life program, a water access and sanitation improvement program commissioned in 2013 has benefited many across East Africa (EABL, 2013).

3.2.1.1 Status of water recycling at EABL

According to information gathered from the reconnaissance visit to the plant, EABL operations rely mainly on water from the Nairobi City Water and Sewerage Company (NCWSC) supply. Reliable water supply is very important to EABL because their products require large amounts of water. In the opinion of the operations manager, interviewed in the reconnaissance visit, beer contains 95% water, while alcoholic spirits averagely contain 40% water. Even though water from NCWSC meets the World Health Organisation (WHO) standards, EABL undertakes further water treatment to achieve the required standards for use in brewing, filtration, packaging washing and condensation processes.

The 2,160,000 cubic meters of water consumed annually and only 10% was reused after secondary treatment. This provided an additional source of water to the plant for tasks like firefighting, general cleaning across the plant, pasteurization, energy generation, landscape irrigation, and toilet flushing. The treatment plant at the time of the study consisted of a precipitation chamber, sand filtration, membrane filtration chambers, reverse osmosis chamber, a pH-adjustment, and chlorine dioxide chamber.

3.2.2 Data needs, types and sources

This study required both quantitative data and qualitative data. For a cost-benefit analysis, quantitative data required included the bill of quantities in US dollars for building a recycling plant at EABL for the current recycling capacity of 216,000 cubic meters per year, representing 10% recycling. The cost of building treatment plants recycling with 25% and a 50% targets per year were required as alternatives to the current 10% capacity. The primary source of this data was from local water engineering firms specializing in building water recycling plants.

Furthermore, an inventory of the benefits of water recycling at EABL inform of qualitative data was needed to provide an insight on the full range of the economic, social and environmental benefits. This data was from primary sources that consisted of key personnel at EABL, water experts, National Environmental Management Authority (NEMA) officials and water recycling firms. However, quantitative data inform of water consumption volumes at EABL, water prices per unit, wastewater disposal charges per unit were required to quantify the benefits of water recycling. This was from both primary and secondary sources.

To assess the challenges associated with water recycling in the manufacturing sector, and Kenya's regulatory framework of water recycling, the data required was largely qualitative from primary sources that included key personnel at EABL, water experts, NEMA officials and water recycling firms. Their information based on the experience in their field was further collaborated with data from secondary sources like consumption records, journals, books among others.

3.2.3 Sampling procedure and data collection

Using a purposeful sampling approach, the study focused on a population that could provide information needed to answer the research questions listed in section (1.3). The goal was to gain a broad range of perspectives by selecting a heterogeneous sample of key informants. The process involved the creation of a preliminary list of potential informants based on education levels, the area of expertise, years of experience, and organizational affiliation. Special attention was paid on those with first-hand experience in water recycling, environmental or water resources law and policy and involvement at EABL production process.

From the review of the preliminary list of 34 informants to ensure diversity of informants, a final list 29 was generated. Emails were sent to key informants in the final list to request their participation in the study, for those who could not be reached by email, they were contacted via telephone. The study targeted to interview 15 to 25 informants as recommended by the (United States Agency for International Development, (1996).

Of the 29 informants contacted, 15 were willing and available for face-to-face interviews. The 15 to 20-minute interviews were conducted using tailored questionnaires (see Appendices 1 and 2) with both closed and open-ended questions. The questionnaires consisted of an introduction to the researcher and the study, a confidentiality clause, and a section, “A”, which sort information about the respondents which was meant to understand their depth of industry knowledge and experience. Other sections were tailored to obtain specific data based on the informant’s background and information required to answer the research questions.

Unlike the primary data, secondary data collection involved the selection sources from a large pool of published and unpublished materials like books, research papers, articles, laws, and reports. They were chosen based on their relevance to the study’s research objectives and their respective themes. This procedure was particularly useful in the assessment of the challenges in the implementation water recycling schemes in the manufacturing industry, and the evaluation of Kenya's regulatory framework of water recycling.

3.2.4 Data analysis

As soon as data collection was complete, recording and duplication errors were removed, data was sorted in relation to the research questions, and then entered into Excel spreadsheets. This was applied for all quantitative data obtained from the key informant interviews and secondary sources.

3.2.4.1 Cost benefit analysis

For the CBA, the first step was to identify and categorize the costs from the responses by key informants as capital and recurring costs. The mean capital and recurring costs of each recycling capacity, 10%, 25% and 50%, was calculated by adding up the sum of all bills under each cost category (capital and recurring costs) as provided by each interviewee.

The second step was the estimation the benefits. The study used a cost-based approach referred to as the avoided cost method. This involved the calculation of avoided cost in the purchase of water from the NCWSC by EABL for all recycling capacities. The avoided costs were the product of the amount of water recycled and prevailing prices per unit as provided by NCWSC. Where a flat rate of six units cost US $ 2.07 per unit, 53 units for US $ 0.54 per unit and the balance at US $ 0.64 per unit. As per NCWSC's charges, 75% of the total cost of water recycled represented the avoided wastewater disposal costs at EABL.

The third step and first among the tests to determine the viability of the recycling projects was the calculation of the worth of the cost and benefits in future considering the time value of money. The future values of the costs and benefits were assessed using a discounting rate (usually the prevailing lending rate). At the time of the study, the Central Bank of Kenya (CBK) lending rate was 12%. As outlined in equation (2), this discounting rate was used in the evaluation of the cost and benefits of the recycling project for a period of 40 years, a standard evaluation period for engineering projects. This process was repeated for all recycling capacities.

$$NPV = \sum_{i=0}^{N} \frac{B_i - C_i}{(1 + rates)^i} - Initial\ Investment \qquad (2)$$

Where: NPV-Net Present Value; N is the evaluation period in years; C_i costs in year i; B_i - Benefits in year ***i*;** $rates$ is the real discount rate (Khan, 1993).

In the fourth step, the Benefit Cost Ratio (BCR) was conducted to establish the monetary value gained from the different recycling project scenarios of either 10%, 25% or 50%. The present values for the benefits were weighed against the present vales of the costs as in equation (3). The assumption was that a BCR greater that one, was an indication of the viability of the project. The greater the BCR the better the project.

$$BCR = \frac{PV\ Benefits}{PV\ costs} \qquad (3)$$

Where: PV is the present value; and BCR is the Benefit Cost Ratio (Khan, 1993)

The fifth step of the CBA process was the calculation of the Internal Rate of Return (IRR). This test given by equation (4) was meant to evaluate the rate at which the different recycling capacities yielded returns on the money invested over different interest or discounting rate scenarios. An 8% and a 20% rates represented the low and higher bound interests scenarios respectively of the 12% rate used for the study.

$$Initial\ Investment = \sum_{i=1}^{N} \frac{B_i - C_i}{(1 + rates)^i} \qquad (4)$$

Where: N is the evaluation period in years; C_i costs in year i; B_i - Benefits in year ***i*;** $rates$ is the real discount rate (Khan, 1993)

3.2.4.2 Assessment of challenges and Kenya's water recycling regulatory framework

For the qualitative data collected for these objectives, data analysis involved a detailed and selective examination of data recorded to evaluate the themes that stood out in the interviews. Attention was paid on specific themes regarding the challenges in water recycling, and laws, policies, institutions governing water recycling. Then a data reduction was done to isolate data that was important in answering the research questions before being categorized into their respective thematic areas.

After the completion of the thematic analysis process, the data was assembled into tables in Excel spreadsheets. Some tables were exported into final tables in Microsoft word, while others were sources of data for generation graphical presentations like graphs and charts. These displays were used in the presentation of the research findings and drawing conclusions for the respective questions. Secondary data obtained from literature was used to collaborate primary information collected from the interviews.

CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter details the results on the research questions in the study and discusses them in relation to existing knowledge. It covers the results of the cost and benefit analysis, highlights the challenges that hinder industrial water recycling and lastly gives an in-depth evaluation of Kenya's' water recycling regulatory framework.

Of the initial sample of 29, 15 informants were successfully interviewed. They included a production manager, a plant engineer, an accounting officer and a procurement officer at EABL, three water engineers from three water recycling firms, four water experts from the University of Nairobi, Kenya Water Institute and Jomo Kenyatta University of Agriculture and Technology and the Water Resources Management Authority. Four NEMA officials from the Environmental Education, legal, planning and compliance departments were interviewed.

4.1 Cost Benefits Analysis of Water Recycling At EABL

The cost benefit analysis considered water recycling project at EABL for a time frame of 40 years, starting 2016 as the base year to 2056. The bank interest rate of 12% was used as the discounting rate. The viability of treatment and reusing water at the brewery was assessed by the evaluating the avoided water and wastewater disposal costs. The current 10% was compared to alternatives of recycling 25% and 50% of the water at EABL.

Having determined the costs of water recycling at EABL, and that EABL recycles 10% of the 2,160,000,000 litres (two billion, one hundred sixty million) consumed annually, a set of costs at different recycling targets were set to determine at which level of recycling for maximum benefits. NWSC sells water in units, where one unit is equivalent to 1000 litres. Therefore, the annual consumption is equivalent to 2160000 units (two million, one hundred sixty thousand). This was the basis used in the CBA.

4.1.2 Quantification of Cost of water recycling at EABL

When asked to list the probable capital and recurring costs of water recycling at EABL, 11 out of the 15 interviewees provided responses summarized in figure 3.

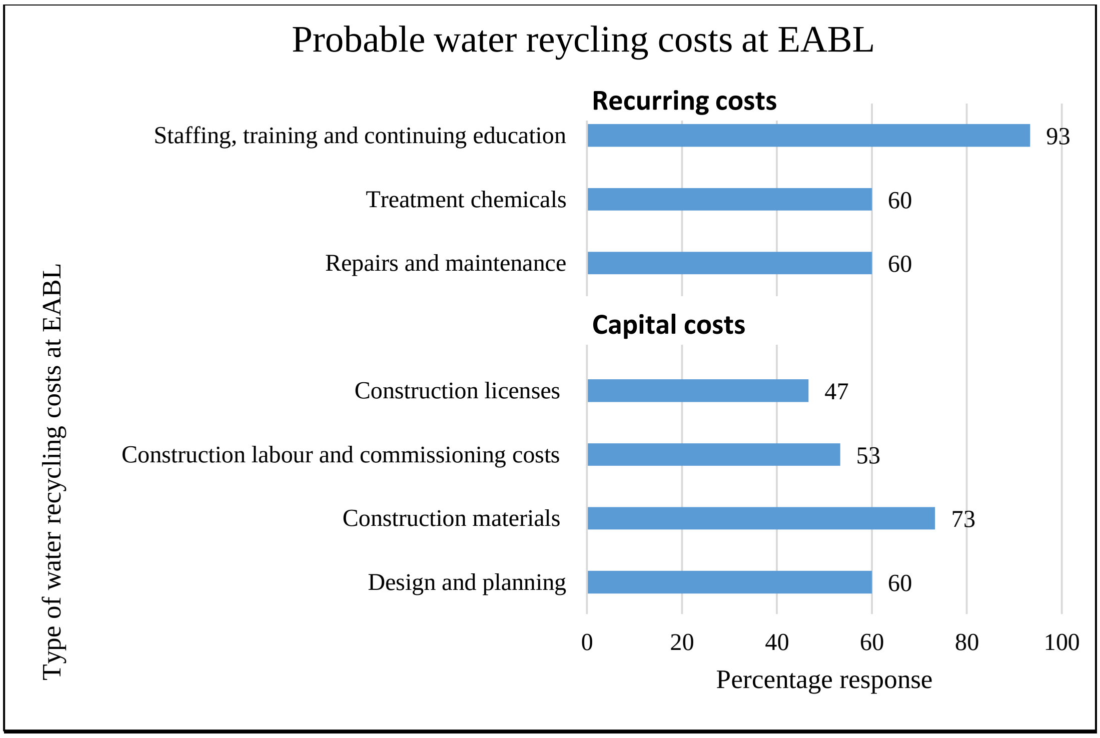

Figure 3.Probable costs of water recycling at EABL

Source: *Survey Data*

From the responses, the key informants demonstrated knowledge on the costs of water recycling for EABL. 93% of the interviewees listed staffing and training to be costs of water recycling, while 60% felt that the purchase of treatment supplies and plant repairs were part of the recurrent costs water recycling. While construction licenses were the list mentioned cost at 47%, the 73% of the interviewees seemed to agree that construction expenses were a key component of the capital costs.

The capital and recurring costs listed by the interviewees in figure (3) are similar to those considered by Chougule & Sonaje (2013); Hertle *et al.*, (2014) Pickering, (2013) and Lahnsteiner & Klegraf (2005). Further analysis revealed that land acquisition was never mentioned in this study. This could be attributed to the fact that EABL is already operational.

4.1.2.1 Capital Costs

To estimate the capital costs of building a treatment to recycle 10%, 25% and 50% of water at EABL annually, three water engineers, affiliated to firms 'A', 'B' and 'C', were asked to provide cost for treatment and recycling plants similar that at EABL. It consisted of a precipitation chamber, sand filtration, membrane filtration chambers, reverse osmosis chamber, a pH-adjustment, and chlorine dioxide chamber for the different recycling capacities. These estimates shown in Tables 1, 2, and 3 are based on the pricing policy of the respective firms the interviewees were affiliated to.

Table 1. Estimated capital costs for 10% recycling.

COSTS	**10% recycling capacity (216,000 units)**		
	Interviewee Firm 'A'	**Interviewee Firm 'B'**	**Interviewee Firm 'C'**
Design and planning	US$ 54,000.00	US$50,235.00	US $35,781.00
Construction materials	US$ 225,000.00	US$ 261,225.00	US$ 210,710.00
labour	US$ 157,500.00	US$ 175,824.00	US$ 147,099.00
Licensing	US$ 22,500.00	US$ 15,070.00	US$ 3,975.00
Interviewee's total capital costs	**US$ 459,000.00**	**US$ 502,356.00**	**US$ 397,567.00**
Mean capital costs for 10% capacity	**$452,974.00**		

Source: *Survey Data*

From the key informant responses at the water recycling firms, the capital costs for recycling 10% of water at EABL averaged at US$ 452,974 as shown in Table (1). The results indicated a variation in pricing by the three firms. This difference could be attributed to the different costing strategies at the three firms. The same interviewees also provided estimates, shown in Table (2), for recycling 25% of water at EABL.

Table 2. Estimated capital costs for 25% recycling.

COSTS	**25% recycling capacity (540,000 units)**		
	Interviewee Firm 'A'	**Interviewee Firm 'B'**	**Interviewee Firm 'C'**
Design and planning	US$104,406.00	US$93,260.00	US $76,221.00
Construction materials	US$435,025.00	US $484,952.00	US $448,857.00
Labour	US$304,518.00	US $326,410 .00	US $313,353.00
Licensing	US$43503.00	US $27,978 .00	US $8,469.00
Interviewee's total capital costs	**US$887,451.00**	**US $932,600.00**	**US $846,900.00**
Mean Capital costs for 25% capacity	US$**888,984.00**		

Source: *Survey Data*

The results also showed a difference in the estimate given by the different respondents from the three firms. The capital costs for recycling 25 % of water at EABL were calculated; they averaged to US$ 888,984 as seen in Table (2). This was almost double the cost of recycling 10% of the wastewater. Table (3) shows the capital costs of having a 50% water recycling capacity at the same brewery.

Table 3.Estimated capital costs for 50% recycling.

COSTS	**50% recycling capacity (1,080,000 units)**		
	Interviewee Firm 'A'	**Interviewee Firm 'B'**	**Interviewee Firm 'C'**
Design and planning	US$228180.00	US$201,100.00	US$170,392.00
Construction materials	US$950750.00	US$1,045,721.00	US$1,003,418.00
Labour	US $665525	US$703,851.00	US$700,500.00
Licensing	US$95075.00	US$60,330.00	.00
Interviewee's total capital costs	US$1,939,530.00	US$2,011,002.00	US$1,893,242.00
Mean Capital costs for 10% capacity	**US$1,947,925.00**		

Source: *Survey Data*

From the information provided during the interview of key informants at water recycling firms, the capital costs for wastewater recycling 50% o averaged to US$ 1,947,925. This was also an increment in cost compared to 10% and 25% recycling. The mean capital costs in Tables 1, 2 and 3 show that the cost of design and planning, construction material and labour, as well as licensing are proportional to the capacity of wastewater treatment plant.

4.1.2.2 Recurring costs

The recurring costs consisted of repairs and maintenance, treatment chemicals and human resource expenses. The estimates of the recurring costs by interviewees from the water recycling firms 'A','B', and 'C' and the means were calculated for each level of recycling are summarized in Tables 4, 5 and 6.

Table 4. Estimated recurring annual costs for 10% recycling

COSTS	10% recycling (216,000 units)		
	Interviewee Firm 'A'	**Interviewee Firm 'B'**	**Interviewee Firm 'C'**
Repairs and maintenance	US$ 1,050.00	US$ 925.00	US$ 1,843.00
Treatment chemicals	US$ 4,320.00	US$ 4,900.00	US$ 7,000.00
Personnel and Training	US$ 11,200.00	US$ 9,210.00	US$ 8,235.00
Interviewee's total recurring costs	**US$ 16,570.00**	**US$ 15,013.00**	**US$ 17,078.00**
Mean recurring costs for 10% capacity	US$**16,220**.00		

Source: *Survey Data*

The results from the survey in Table (4) showed that the average recurring annual costs for recycling 10 % of water at EABL was US$ 16,220. These annual costs for repairs, treatment chemicals, and human resources varied from one firm to another.

Table 5. Estimated recurring annual costs for 25% recycling

COST	25% recycling (540,000 units)		
	Interviewee Firm 'A'	**Interviewee Firm 'B'**	**Interviewee Firm 'C'**
Repairs and maintenance	US$ 2,625.00	US$ 4,050.00	US$ 3,760.00
Treatment chemicals	US$10,800.00	US$ 9,500.00	US$ 6,040.00
Personnel and Training	US$ 28,000.00	US$ 37,012.00	US$ 15,000.00
Interviewee's total recurring costs	US$ 41,425.00	US$ 50,562.00	US$ 24,800.00
Mean recurring costs for 25% capacity	US$ **38,929.00**		

Source: *Survey Data*

On further probing, it was found that recycling 25 % of water at EABL annually would cost USD 38,929 in recurrent expenditures detailed in Table (5). This was more than twice the recurrent costs for recycling 10% of at the same brewery. Additionally, the estimates, summarized in Table (6) showed that recycling 50% of the wastewater would cost averagely US$ 69,858 annually. Again, this was higher than recycling 10% and 25%. This trend was also similar that of capital costs where higher capacities required bigger investments.

Table 6. Estimated recurring annual costs for 50% recycling

COST	50% recycling (1,080,000 units)		
	Interviewee Firm 'A'	**Interviewee Firm 'B'**	**Interviewee Firm 'C'**
Repairs and maintenance	US$ 5250.00	US$ 7,020.00	US$ 4,100.00
Treatment chemicals	US$ 21600.00	US$ 15,300.00	US$ 10,000.00
Personnel and Training	US$ 56000.00	US$ 60,300.00	US$ 30,000.00
Interviewee's total recurring costs	US$ 82,850.00	US$ 82,620.00	US$ 44,103.00
Mean recurring costs for 50% capacity	**US$ 69,858.00**		

Source: *Survey Data*

4.1.2.3 Total cost of water recycling at EABL

With the recurrent and capital costs of recycling the various capacities determined, the total costs for recycling were calculated by summing up the mean capital costs and annual recurring costs for each level of water recycling.

Table 7. Total costs for recycling at EABL

COST	10% recycling	25% recycling	50% recycling
Mean capital costs	US$ 452,974.00	US$ 888,984.00	US$ 1,947,925.00
Mean Recurring costs	US$ 16,220.00	US$ 38,929.00	US$ 69,858.00
TOTAL COST	**US$ 469,194.00**	**US$ 927,913.00**	**US$ 2,017,783.00**

Source: *Survey Data*

The results in Table (7) revealed that the total estimated cost of recycling 10% of the wastewater at EABL amounted to US$ 469,194 while it was found that it would cost

US$ 927,913 to recycle 25% of the wastewater, US$ 2,017,783 would be needed to recycle 50% of wastewater at the brewery every year. The trend of the increase in coast with increased recycling capacity was expected given the relationship between the capital and recurring costs with the increase in recycling capacity.

These results build on the previous studies by providing clear findings from a clear methodology. Studies by Chougule & Sonaje (2013); Hertle *et al.*, (2014); Pickering (2013) and Lahnsteiner & Klegraf (2005) discussed in the literature review did not show how they arrived at the costs of their recycling projects. More importantly, the findings of this study are significant because they revealed the strong correlation between costs and recycling capacities.

4.1.3 Quantification of the benefits of water recycling at EABL

When asked to outline potential benefits of water recycling at EABL, the responses from the 15 interviewees detailed at the beginning of this chapter fell in economic, environmental and social categories.

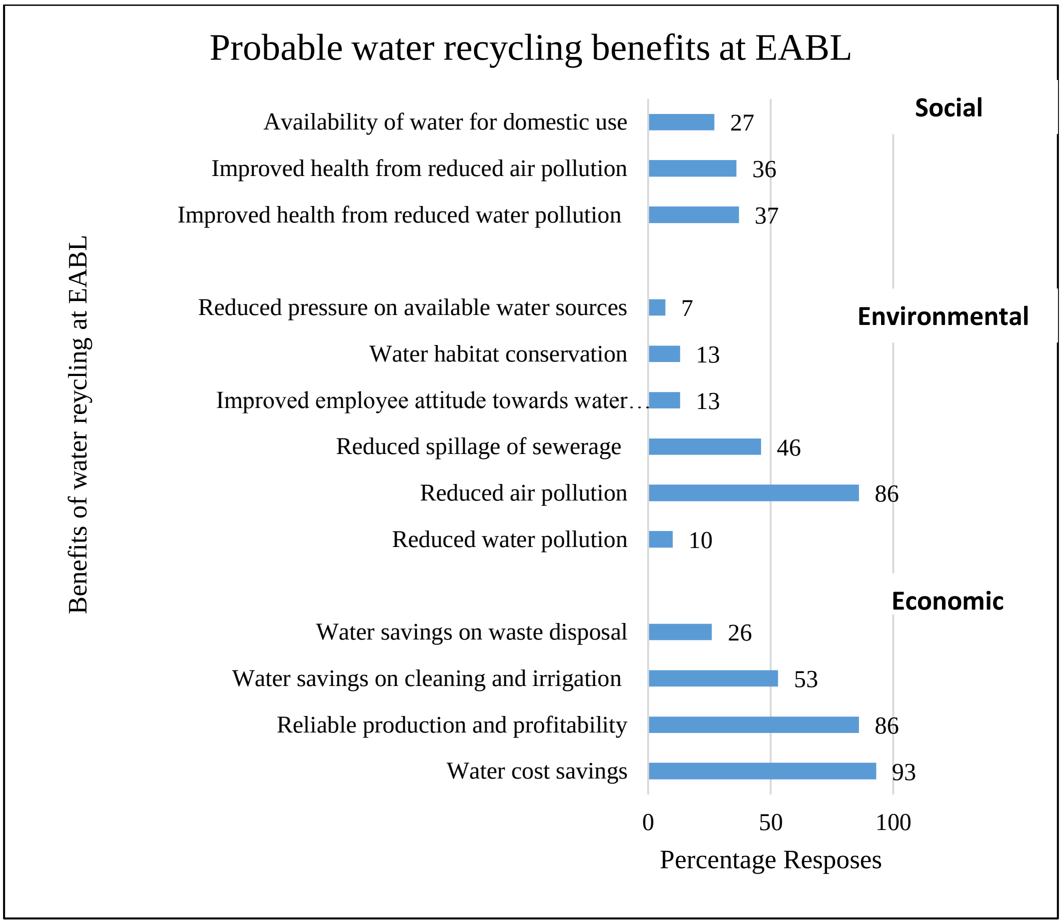

Figure 4. Probable benefits of recycling water at EABL

Source: *Survey data*

Results from the survey shown in figure (4) revealed that majority of the key informants interviewed felt that water recycling would save the costs of purchasing water at EABL, reduce air pollution, and increase the profitability of the brewery because it will be a source of reliable water. Surprisingly, very few interviewees, 10% , and 7%, felt water recycling would reduce water pollution and reduce pressure on water sources like surface and groundwater respectively. Savings on water disposal discussed by Hertle *et al*, (2014) was only mentioned by 26% of the key informants.

4.1.3.1 Economic benefits of water recycling

The option was that EABL would finance the project with a loan at a prevailing interest of 12% annually, with the project done in phases of 50%, 30%, and 20%. A grace period of 3 years was considered after which the interests would be paid. Like any infrastructure project, the water recycling plant was subject to depreciation and it was assumed that 10% would be salvaged after the evaluation period of 40 years.

Using the avoided cost method detailed in step two of the data analysis, the study considered economic benefits of recycling water at EABL to be the saving from purchasing water (avoided water purchasing costs), and the savings from wastewater disposal (avoided wastewater disposal costs). These total economic benefits in Table (8) were determined by calculating how much it would cost to purchase water and dispose 10%, 25%, and 50% of recycled water quantities based on NCWSC's pricing policy detailed in Section 3.2.4.1.

Table 8. Annual economic benefits of water recycling at EABL

Economic Benefits	**10% recycling**	**25% recycling**	**50% recycling**
1. WATER COST SAVINGS			
Volume	216,000 units	540,000 units	1,080,000 units
First 6 units at US$ 2.07	US$ 2.07	US$ 2.07	US$ 2.07
Second 53 units at US$ 0.54 each	US$ 28.62	US$ 28.62	US$ 28.62
Balance at US$ 0.64 each	US$ 138,202.24	US$ 345,562.24	US$ 691,162.24
Water savings	***US$ 138,232.93***	***US$ 345,592.93***	***US$ 691,192.93***
2. WASTEWATER DISPOSAL SAVINGS			
Disposal savings (75% of Total Water cost)	US$ 103,674.70	US$ 259,194.70	US$ 518,394.70
TOTAL ECONOMIC BENEFITS (Avoided costs)	**US$ 241,907.63**	**US$ 604,787.63**	**US$ 1,209,587.63**

Source: *Survey data*

The NCWSC charging system was a flat rate of US$ 2.07 for the first 6 units of water consumed, additional 53 units at US$ 0.54, and the remaining units at a rate of US$ 0.64. Based on the consumption levels and proposed recycling capacities, the estimated cost savings for purchasing water were US$ 138,233, US$ 345,593 and US$ 691,193 for 10%, 25%, and 50% recycling respectively. They were added to the savings on wastewater disposal being US$ 103,675, US$ 259,195and US$ 518,394 for 10%, 25%, and 50% recycling respectively.

These results are a major achievement compared to preceding CBA studies done by Chougule & Sonaje (2013); Hertle *et al.*,(2014); Pickering (2013) and Lahnsteiner & Klegraf (2005). Accompanied by a clear methodology, these results are important to the body of knowledge on water recycling in the manufacturing sector. While Lahnsteiner & Klegraf (2005) used a different discounting rate of 10% for an evaluation of 20 years, compared to 12% and 20 years by this study, the results are consistent in showing that they are economic benefits of watering in the manufacturing sector.

4.1.4 Cost benefit tests

The Net present value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR) were measures used to assess the viability of the project. The viability of the 10%, 25% and 50% levels of recycling were considered using the estimated cost total benefits and costs in Tables (7) and (8)

4.2.4.1 Net present value (NPV)

The NPV for 10% recycling was USD 865,038, USD 2,485,167 for 25% recycling and 4,788,972 for 50% recycling. When equation (2) in section 3.2.4.1 of this report was applied to these values, NPV were 0.86, 2.48, and 4.79 for 10%, 25%, and 50% recycling respectively. Based on the rule that for an NPV more than zero, the project is considered viable, these results proved that water recycling at EABL was feasible for the three capacities. As shown in Figure (5), a strong correlation between the NPV and recycling capacity also emerged. The NPV increased with the recycling capacity meaning all recycling level were beneficial and the bigger the investment the bigger the economic benefits. This relationship had not been established before by previous studies reviewed during this study.

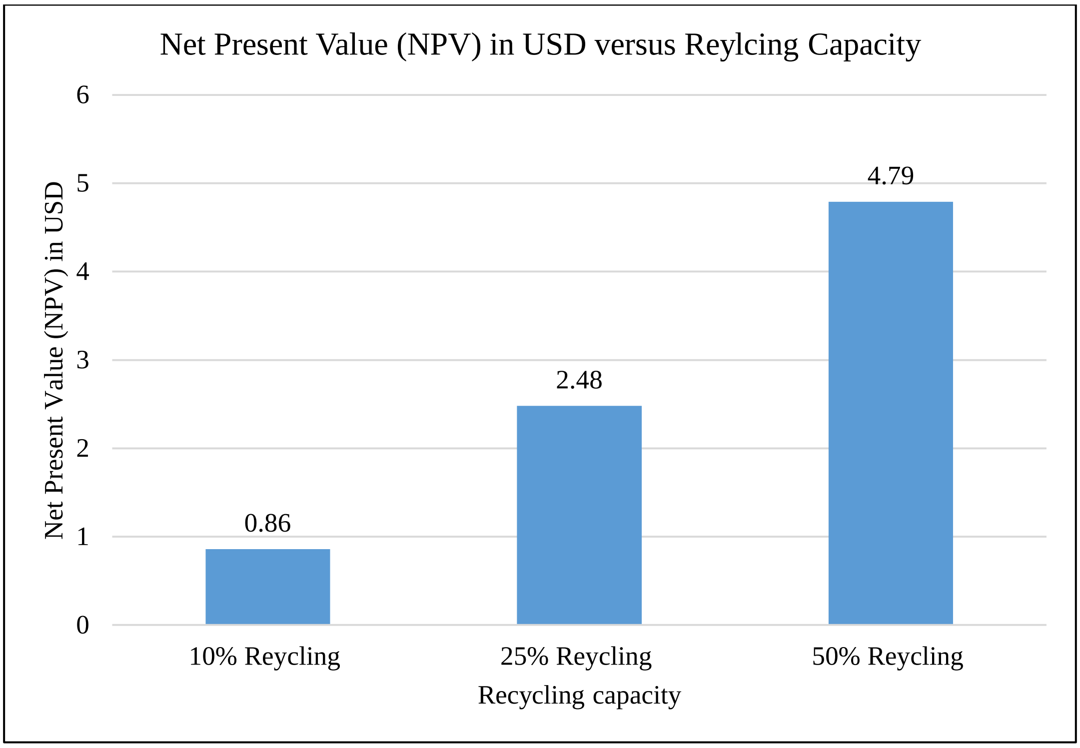

Figure 5. Net Present Values for different recycling capacities

Source: *Survey data*

4.2.4.2 Benefit Cost Ratio (BCR)

The BCR given by Equation (3) in Section 3.2.4.1 was the second test used to assess the viability of water recycling at EABL. It assessed the return per dollar invested in the each project option. As a rule, a BCR more than one indicates that the project is viable. For 10% recycling, the ratio was 3.11, while it was 3.65 and 4.01 for 25% and 50% respectively. For all the recycling levels, the BCR was more than one; this implied that the benefits were more than the cost. As shown in Figure (6), the BCR increased with recycling capacity. For 10% recycling, the benefits were 3.11 times more than the costs while the benefits were 3.65 and 4.01 times more than the costs of the projects.

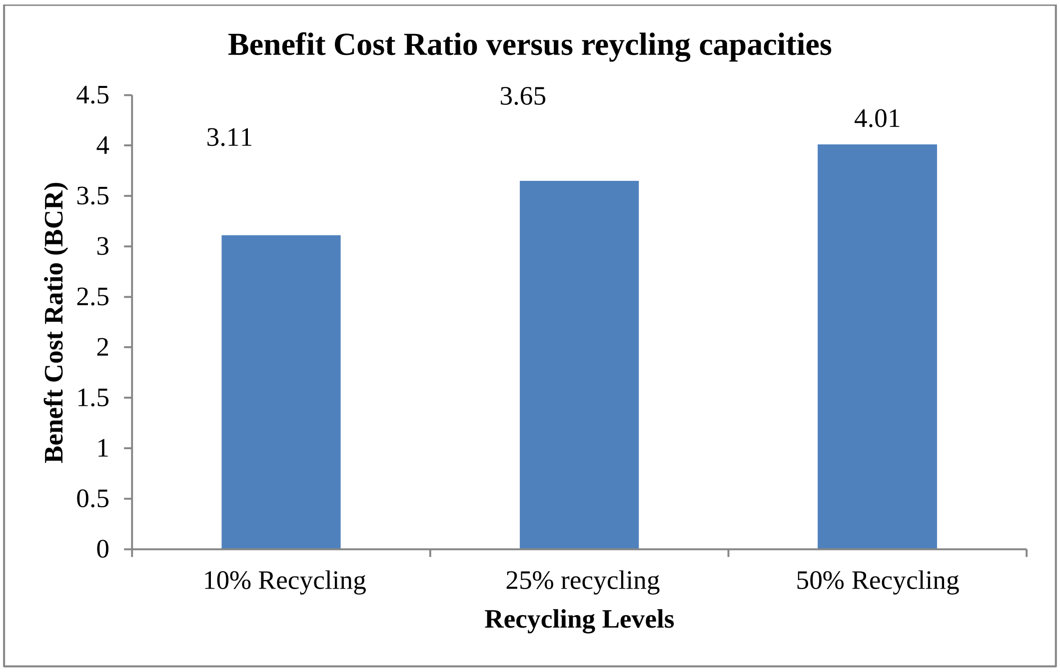

Figure 6. Benefit Cost Ratio for the different recycling capacities

Source: *Survey data*

4.2.4.3 Internal Rate of Return

This was the last test to be performed to assess the viability of water recycling at EABL, using Equation (4) in Section 3.2.4.1. It evaluated the performance of the different recycling capacities in different interest scenarios, 8%, 12% and 20% because changes in interest rates affect the profitability of the projects. The analysis showed that the returns for each recycling alternative remained constant in different interest scenarios shown in Figure (6). This meant that whether the interest went above or below the 12% interest rate used in this study, the projects would be viable.

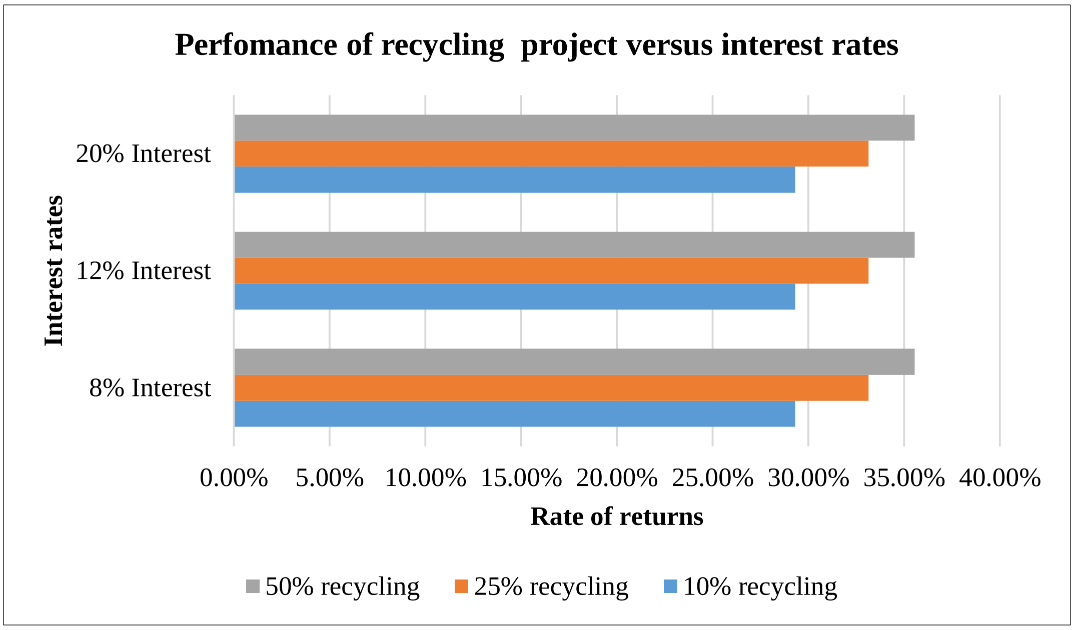

Figure 7. IRR at different levels of recycling

Source: *Survey data*

Unlike other studies done by Chougule & Sonaje (2013); Hertle*et al.*, (2014); Pickering (2013) and Lahnsteiner & Klegraf (2005), this studies through the tests like NPV, BCR and IRR were able to prove the viability of the recycling options at EABL. This is a major contribution to the body of knowledge not only regarding the

CBA process but also on the overall determination of the viability of water recycling in the manufacturing sector.

4.1.5. Environmental and social benefits of water recycling

These economic benefits discussed in Table (8) represent the lower boundaries of the benefits of industrial water recycling. According to the United States Environmental Protection Agency (n.d) apart from providing alternative and reliable water supply, water reuse can tremendously reduce diversion of water from susceptible ecosystems. Consequently, the preservation of such habitats has a huge bearing on the efforts in the conservation of biodiversity. On the other hand, the reduction of effluent production because of wastewater recycling can be beneficial in guaranteeing downstream uses for water resources while enhancing riparian habitats.

Socially, recycled water can improve access to water at domestic level by reducing industrial water withdrawals. The availability of water to households has a multiplier effect. For instance, to education and less time could be spent by school going children to fetch water. In a study by (Hensher, Shore, & Train, 2006), it was found that water consumers were prepared to pay relatively little to avoid low levels of restriction, but up to USD 239 per year to avoid longer water rationing.

On public health, the reduced restriction for household use consequently improves sanitation and causes of waterborne diseases. According to Pickering, (2013), the use of recycled water for irrigation of open public spaces during periods of restrictions can positively affect the mental and physical health of users. There are other positive social benefits linked to recycling water. Friedler *et al.*,(2006); Hartley (2006); Chen, *et al*., (2015) indicate that in the use of recycled water for irrigation of public spaces, microclimates effect could exist, this reduces temperatures in the surroundings and in turn cooling costs to neighbouring homes, or the uneasiness for those with no air conditioning.

4.2 Challenges in the Implementation of a Grey Water Recycling

From responses given by the 15 key informants, several challenges were noted. Results summarized in Figure (8) showed that public perception, a weak regulatory framework, lack of incentives, the high cost of building water treatment plants and the lack of information on the real benefits of water recycling were some of the challenges mentioned by more than 50% of the informants.

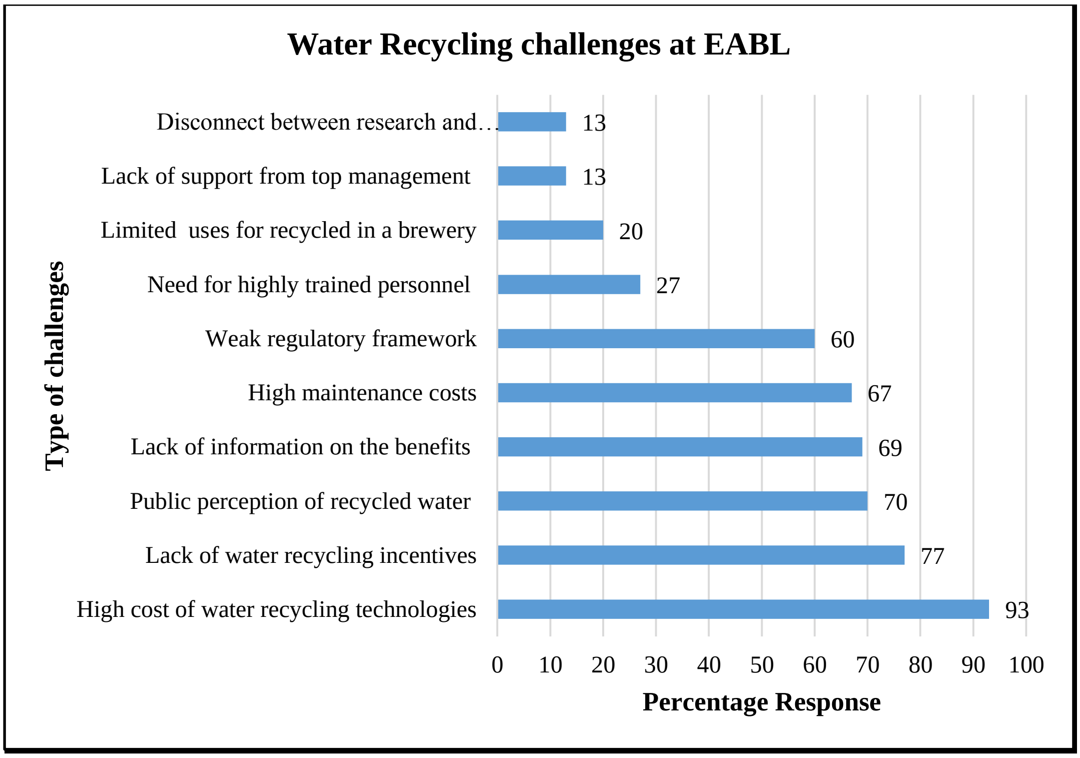

Figure 8. Challenges that hinder water recycling at EABL

Source: *Survey data*

From the survey the main challenges were: the high cost of water recycling technologies (93%); weak regulatory framework (60%); high cost of maintenance of recycling plants (67%); lack of water recycling incentives (77%); public perception of recycled water(70%); and inadequate information the benefits of water recycling(69%). Surprisingly, some challenges like the lack of support from top management (13%), the uncertainty and disconnect between research and implementation (13%), limited uses of recycled water at EABL (20%) and need for highly trained personnel (27%) were considered as challenges by only less than 50% of the informants. Those challenges that 50% of the informants felt were an impediment to water recycling at EABL are discussed in the subsequent parts of this section.

4.2.1 Inadequate regulatory framework

From the results in Figure (8), 60% of the interviewees felt the inadequate regulatory framework was a challenge. When the 15 informants were asked to rank Kenya's regulatory framework on a Likert scale, the felt it was weak, at shown in Figure (9), it averaged 2.07 on a scale of one to five. 66.7% of the 15 respondents considered Kenya's strength of the regulatory framework on water recycling to be weak, 13.3 % considered it to be very weak and 20% were not sure whether to rate it as weak no strong.

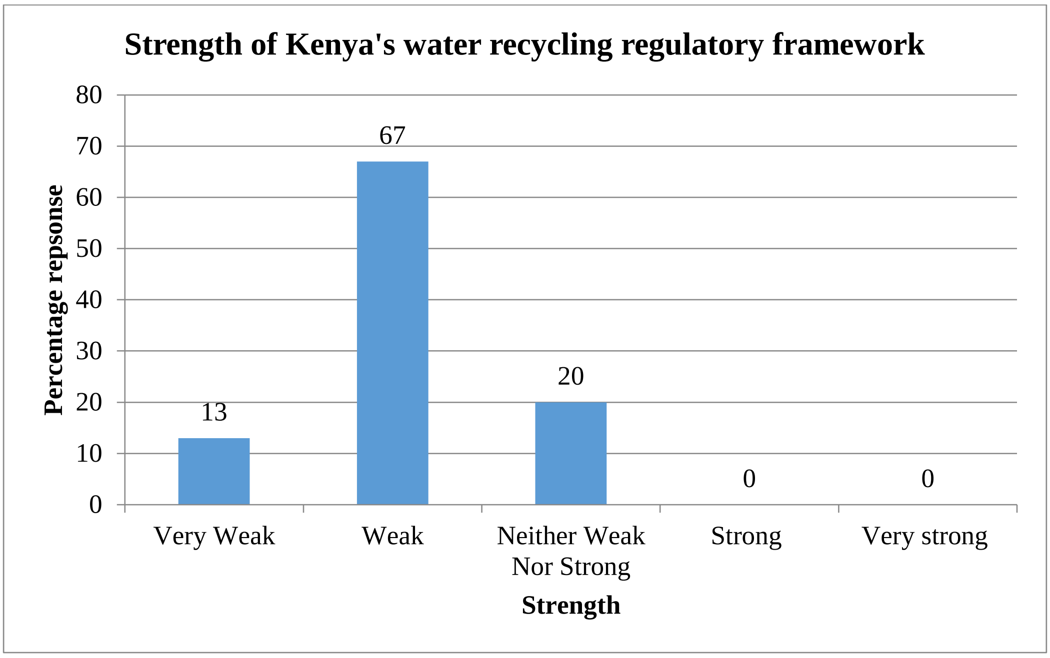

Figure 9. Strength of Kenya's regulatory framework on water recycling

Source: *Survey data*

These findings are supported by Onjala (2002), who observed that Kenya's regulatory framework tends to lean towards 'end pipe control', as observed from the laws and regulations in the water sector. Kenya's licensing was focused of effluent discharge to sewerage systems, water supply, abstraction, groundwater drilling, and discharge of effluent into water bodies. The focus or obsession towards the control of discharge rather than the minimization of wastewater produced in the manufacturing industry does not encourage recycling activities. This counterproductive approach is contrary to the global direction of 'green' production.

Further, a good regulatory framework clearly defines the mandate of established institutions for the purpose of effective administration and enforcement of their respective mandate. Kenya's regulatory framework fails to allocate water recycling mandates for any of the existing institutions among them NEMA, WRMA, Public Health Board, and the water services board. Without a lead institution to guide all issues of water recycling, the challenge is that there is no clear direction and concerted efforts to make water recycling attractive to investors.

Unlike in Kenya, where no single institution was tasked with overseeing water recycling activities, in the Unites States, the Environmental Protection Agency (US EPA) regulates many aspects of wastewater treatment and drinking water quality, and most states have established criteria or guidelines for the beneficial use of recycled water. Indeed, water recycling programs are more successful when implemented as an overlay to coherent regulatory regimes.

4.2.2 Public perception

With 70% of the informants listing public perception as a challenge in recycling water (Figure 8), these findings gave credence to O'Donohue's (2009) observation that the negative public perception is a psychological hurdle in water recycling because the term 'treated water' plays into the intuitive concept of 'contamination' or 'dirty' which makes acceptability to recycled water a huge obstacle. The "yuck" factor, or disgust in psychological terms, is a barrier to water reuse as cited by Po, Kaercher, & Nancarrow (2003).

More interestingly, the informants from EABL revealed that the challenge of using recycled water in production or cooling, or cleaning would be the negative impact on the acceptability of their products in the market. EABL being a food processing industry, they felt the association of treated in brewing could have detrimental effects on their sales. The overall suggestions were that the use of recycled water at EABL should be limited to few purposes. This is in complete agreement with Friedler *et al.,* (2006) who felt that in sensitive industries, recycled water use should be limited to low and intermediate human contact uses like landscape irrigation, cleaning of pavements, firefighting.

In Kenya like other countries, recycled water use may face opposition and clear policies and strategies need to be in place to tackle this challenge. In San Diego, US, a proposal to use recycled water as a water source for the city had remarkable support for the technical experts but failed to materialize. This was due to public opposition mainly because of public health, and environmental concerns (Hartley, 2006). With the low literacy levels in Kenya, the opposition is bound to be even stronger and even greater efforts are required to increase acceptance of recycled water.

The reason for non-acceptance is also the lack of public awareness of treated wastewater and its potential to provide an alternative and steady source for water. With awareness creation, public perception on the use of recycled water can improve, starting from the non-contact and non-potable uses (Marks, 2006). According to Chen *et al.,* (2015), successful implementation of water recycling programs requires public involvement.

Nonetheless, there is potential to increase the public acceptance of recycled water nationally, especially with the agenda-setting window of concern over water scarcity and pollution of water bodies. Likewise, the modernization, economic expansion, rapid development of public and social media present a decent opportunity for awareness creation and acceptance of grey water. Leverenz, Tchobanoglous, & Asano

(2011) observed that public acceptance is the most important issues in the success of water reuse proposals.

4.2.3 High cost of water recycling projects

From the survey results in Figure (8), 93% of the informants felt the high cost of water recycling technologies was a hindrance to water recycling at EABL. Some of the justifications given on why water recycling was capital intensive included the requirements EIA/SEA during the planning and implementation stages, project design and planning costs, constructions costs, labour costs, legal fees and licensing, administration and overhead costs, as well as operational and maintenance costs.

Another reason was that in most cases, water recycling technologies were not readily available locally and required importation, which added to the high costs. These costs are either onetime costs or recurring over a very long period. While such an investments can be a huge financial burden for industries in the developing world, the justification of their viability based on the CBA would encourage investment in water recycling projects by manufacturing industries.

4.2.4 Inadequate incentives for industrial water recycling

The inadequate financial incentives in Kenya make it difficult for industries to adopt water recycling. This was the observation by 77% of the 15 informants that participated in the survey summarized in Figure (8). Many felt that apart from Kenya not having a clear pricing strategy to stimulate reuse, the impact of water price increase in Kenya could have negative repercussions on industries. This is consistent with the suggestion by the Organisation for Economic Co-operation and Development

(2009) that pricing incentives can safeguard the industries and promote adoption of technologies.

In the US for example, grants are awarded for water reuse and reclamation. Several states including, California, Florida, Texas and Washington provide for funding planning, designing and construction of water recycling projects. Subsidies to encourage investment in research, development, and adoption of water recycling, and subsidies in technology transfer are nonexistent in Kenya (GE Power and Water, 2011)

Lastly, the existing mechanisms to reduce pollution do not stimulate investment in water recycling technologies. Elsewhere, water quality trading programs allow firms with high discharge costs to purchase discharge reduction credits from other firms. An example is the US EPA, which sets Watershed Pollution Reduction Goals using the US Water quality Reduction Policy (2003). Regulated wastewater point sources at risk of exceeding permitted discharge limits are allowed to purchase water quality credits from other sources. These programs encourage higher treatment levels for wastewater as facilities attempt to comply with discharge limits (Branosky, *et al.,* 2009)

4.2.5 Inadequate emphasis on the value of water recycling

The lack of understanding of the net benefits of water recycling is a major hindrance to water recycling projects. This is according to 69% of the 15 interviewees shown in Figure (8). Even though feasibility studies have been undertaken elsewhere, the view was that it is difficult and demanding to interpret those findings in the local context.

One key informant said the top management of EABL was reluctant to upscale water recycling due to lack of clarity of the returns on resources invested.

With the information gap, it is difficult to convince investors in water recycling for any firm. According to Pickering (2013), the major inconsistency in the development of feasibility assessments of recycled water projects relates to the incorporation of environmental and social benefits and costs into the assessment framework. Many non-potable recycled water projects have not proven financially viable compared to alternative water supply options, and thus their relative environmental and social costs and benefits become central to assessing their economic value.

4.3 Regulatory Framework on Water Recycling

A regulation is a law, rule, or other order prescribed by authority, especially to regulate conduct. On the other hand, a framework is a model or a skeletal structure that supports or encloses something. Concisely, a regulatory framework is a model that can used for reforming and enacting regulations in an effective and rational manner. The main components of a water management regulatory framework may include but not limited to; water policies, water sector strategies, master plans, water management institutions, water acts, water management provisions in bylaws, among others. In this context, the success of water recycling and management depends on the strength and harmony of Kenya's regulatory framework.

4.3.1 Global policy direction on water recycling

Globally, the United Nations Environmental Programme (UNEP) and the World Business Council for Sustainable Development are responsible for championing the clean production agenda. In recent past, there has been a shift in Europe and, more recently, in North America, away from "end-of-pipe" approaches to industrial waste management towards waste minimization strategies (Seadon, 2010). SDG 6 in an effort to ensure access to water and sanitation for all recognizes the importance of water recycling and encourages the support for water treatment technologies.

In China, for example, recycled water reuse is a national policy and Beijing has the largest-scale and most successful water reuse program in the country (Chen *et al.*, 2015). In Canada and United States, policies have gone further to establish award programs to give recognition for outstanding waste minimization by companies. This is a good idea that indirectly encourages companies to adopt new technologies to minimize wastewater production including water recycling.

As found by this study, the major undoing of Kenya's regulatory framework is that is places a lot of emphasis on control over the discharge with little efforts in the reduction of wastewater production. This is a divergent position from the global best practices in Canada, Australia, unites states among others. The general policy direction in wastewater management produced from domestic, commercial and industrial activities is that regulation of discharge using a command and control approach. This is evident from the numerous regulations on effluent management, and little effort to minimize the production of the wastewater. In the entire water sector regulations reviewed during this study, no clear guides on water recycling were found.

One fundamental step in mainstreaming water recycling seen during the study was in Kenya's ambitious development blueprint, Vision 2030. It views water as an essential that supports the development activities planned under the 2030 master plan. This plan was mindful of the fact that water supply and sanitation are greatly affected by climate change. It recommended adoption of new technologies to support the existing single measure of demand management and leakage management. However, in increasing the available water resources, this plan was keen on desalination of coastal water as a potential water source. Like other plans and policies in Kenya, there was little recognition of the importance of grey water recycling in addressing the water scarcity and wastewater management problems.

4.3.2 Water recycling related policies in Kenya

From the review of the National Water Policy (2013), a policy direction of future water management for Kenya was provided. It included treating water as a social and economic good, preservation, conservation, and protection, as well as sustainable and economical allocation of water resources. It was keen on the provision of adequate amounts of water, ensuring safe wastewater disposal for environmental protection, development of a sound and sustainable financial system for effective and efficient water resources management. Similarly, there was no attempt to consider water recycling as a potential solution to the biting water scarcity and water degradation challenges.

According to Onjala (2002) a few water policy instruments in Kenya have been adopted and many remained in the formative stages. Those that have been adopted include the effluent standards, licensing of water supply and disposal, and privatization of water supply. Of major importance but still remain non-existent were; wastewater generation quotas, mandated policy recycling percentages, industrial ecology management within industrial complexes and technology transfer of efficient equipment and processes.

Further analysis of secondary literature showed that economic incentives and disincentives play a huge role in encouraging best environmental practices for firms (Clemens, 2006). However, Onjala (2002) observed that in Kenya, there were no stipulated penalties on violation of quotas in wastewater generation and no subsidies that encourage investments in water recycling. Subsidies in research and development, and adoption of wastewater recycling technologies were missing. Even though there are major concerns across all sectors on whether policy directions can translate into concrete and productive action, guidelines and policy incentives are still needed because water recycling offers a solution for both water scarcity and wastewater management.

The National Water Management Strategy (2006-2008) by the Ministry of Water and Irrigation, recognized water scarcity, underdevelopment of water resources, climate change, catchment area degradation and deterioration of water resource assessment as the main issues and challenges in water management. While doing so, it also failed to recognize the uptake of water reuse technology and subsequent implementation of water recycling schemes as a challenge in water management and conservation.

4.3.3 Water recycling institutional arrangements

It was found that water management in Kenya falls under the purview of the Ministry of Water and Irrigation and the Ministry of Environment and Natural Resources (MENR). The respective county governments were involved in the administration of matters related to water resources. At a lower level, WRMA and Water Service Boards established under the Water Act 2002, and NEMA, established under section 42 of the Environmental Management and Coordination Act 1999.

The MENR was charged with the formulation of wastewater standards especially in industrial effluent management by treatment, and ensuring discharge does not have unacceptable levels of toxicity or degradation of water bodies. Further, NEMA set out guidelines on irrigation water quality and quality requirements for discharge into the environment. Schedules 3, 8, 9 and 10 of the NEMA water quality standards give the quality guidelines for water to be discharged into the environment or to be used for irrigation or recreational purposes (Environmental Management and Coordination Waste management regulations, 2006).

Even with the numerous water sector institutions, there was no lead institution to spearhead activities in water recycling. This conclusion was reached after a review of the respective mandates of the institutions detailed in this chapter. It is unimaginable that water recycling, a popular solution to the water scarcity and wastewater management problems, does not have institutional arrangements.

4.3.4 Water recycling regulations

From the review of water-related laws, the provisions on water recycling were very scanty. The Environmental Management and Coordination Waste management regulations (2006), formulated by the MENR, provide for industrial effluent management by treatment to ensure discharge does not have unacceptable levels of toxicity or degradation on water bodies.

Surprisingly, most of the legislations are keen on rights, the establishment of institutions, effluent discharge, and pollution. For instance, under the Kenya Constitution (2010), water is under natural resources and the environment. Article 42 is the very foundation of environmental management and conservation. "*Every person has the right to a clean and healthy environment, and that the environment should be protected for the benefit of present and future generations through legislative and other measures"* (Ibid). Article 69 further requires the state to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources that include water resources.

In the same breadth, the Environmental Management and Coordination Act (1999) echoes the spirit of the Kenyan Constitution by emphasizing on the right to a clean environment and establishes NEMA, mandated with the administration and enforcement of environmental regulations. Section 72 of this act prohibits water pollution while Section 74 requires all industries to discharge waste to sewerage systems after licensing provided in Section 75. Further, this act recommends formulation of standards for waste (including wastewater) handling, transportation, by the ministry under the leadership of the cabinet secretary. This was provided for under Section 85. Like others, water recycling was not provided for in any of the available sections.

The Water Act (2002)**,** an important legislation in water management and particularly grey water recycling, falls short by not providing guidance on water recycling. Under this act, clear provisions would have answered questions including whether a permit is required for water recycling, as well as necessary standards for different water uses.

Apart from establishing the WMRA and water service boards, it requires permits for draining swamps, and discharge of pollutants into water bodies. A new draft of this act, the water bill 2014, was still in its formative stage at the time of the study.

Lastly, the Food, Drugs and Chemical Substances Act (2002) is an important piece of legislation concerning water recycling at EABL and other food processing industries. The production of beer is subject to provisions of this law. This act establishes the Public health (standards) board that is in charge of administration and enforcement of standards that safeguard public health. However, there is no particular regulation touching on recycled water use in the manufacturing sector. This is a huge gap that makes it difficult for industry players to use recycled water, and even more difficult in the enforcement of quality standards.

From these regulations reviewed in this study, among them, the Agriculture Act Cap 318, the Water Act 2002, the Environmental Management and Coordination Act (1999), Food, Drugs and Chemicals Substance Act 2002, and the Water quality regulations 2006, no single legislation provided for water recycling. The regulations neither gave guidance on water recycling, licensing nor recycled water reuse standards. This could be the reason why 60% of the interviewees felt the inadequate regulatory framework was a challenge. In fact, 66.7% of the interviewees considered Kenya's strength of the regulatory framework on water recycling to be weak. This is as shown in Figure (8).

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Water recycling after appropriate treatment remains an important alternative for the economic, social, and environmental sustainability of manufacturing industries and our cities. Whereas many companies have followed the trend of green technologies, the slow adoption of industrial water recycling has been because of the inadequate information on its benefits, as well as the ambiguity of the challenges and regulatory measures.

The evidence from this study at EABL confirms that water recycling in the manufacturing sector is economically beneficial. This was validated by the NPV test which suggested the value of the water recycling investment for all recycling capacities will be bigger in the future, and the BCR test which also proved that the benefits for all the recycling capacities were more than the costs. Further, the IRR test confirmed that the benefits of recycling any of the capacities at EABL were constant regardless of changes in interest rates or inflation.

Taken together, the challenges identified by the study among them; high costs the technology, inadequate information on the value of recycling water, absence of incentives, weak regulatory framework and the negative public perception of recycled water, all point towards the enormous task facing water sector players in stimulating water recycling in Kenya's manufacturing sector. Likewise, the findings suggest that Kenya's regulatory framework on water recycling was focused on 'end pipe control' rather than the reduction of wastewater production. Kenya also lacked water recycling strategies, and an institution to spearhead water-recycling activities at industrial and even domestic levels.

This study not only added valuable insight to the existing work in ascertaining the benefits of water recycling in the manufacturing sector but also managed to provide a backbone for the understanding of the challenges and regulatory frameworks on water recycling, areas that had been neglected before. The findings on the CBA, evaluation of challenges, and regulatory framework on water recycling can be relied upon by scholars as a springboard for their research. These results can also be used for decision making by industry players to encourage the implementation of water recycling. More importantly, the study was successful in providing a local context of the discussions on the benefits, and the challenges of water recycling in the manufacturing sector.

5.2 Recommendations

- The picture on the benefits of water recycling in the manufacturing sector remains incomplete because the study was limited to the economic benefits. It is possible that the benefits would be even higher if the environmental and social benefits were considered in the evaluation. This would have required more resources and other robust techniques to value items like clean air, beautiful landscapes, among others, which do not have market prices.

- To solve the problem of the high cost of recycling projects found by the study, there is need to come up with strategies to increase private and public sector partnerships, provide subsidies in the importation of water recycling technologies, provide grants for water recycling projects, and facilitate capacity building in water recycling.

- Awareness creation is also needed to improve public perception on the use of recycled water with potential for non-contact and non-portable uses. Attention should be paid on delinking the notion of 'contamination' from treated water.

- Kenya's laws related to water reuse need to be harmonized and if need be new laws formulated informed by the prevailing challenges highlighted by this study. This ought to be based on the water quality needs of different sectors, and available contact and non-contact recycled water uses considering public health and the environment.

- There should be a shift in the policy direction from end pipe control to reduction of production of wastewater not only in the manufacturing sector but also in the domestic realms. Watershed Pollution Reduction Goals ought to be set and reward programs formulated to encourage wastewater recycling in the manufacturing sector. Kenya should consider water quality demand trading an idea similar to carbon trading to encourage recycling.

- To ensure water recycling concerns are properly addressed, there is need to allocate the mandate of licensing, administration and management of water recycling to a single institution to ensure investors have a one-stop shop for information and services. Such a model would be similar to the Energy Regulatory Commission (ERC) spearheading green energy solutions Kenya's energy sector.

5.3 Suggestions for further research

- There is need to conduct Cost Benefits Analysis studies at the domestic level to complement the studies done in the manufacturing sector. This could expand the reach of water recycling technologies for a bigger impact on the reduction of water scarcity, and wastewater management problems.

- To stimulate water recycling, studies should ascertain the cause of a negative public perception of products manufactured by recycled water to inform awareness creation strategies.

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