Carbon and water footprint for a soft drink manufacturer in South Africa

by

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submitted in accordance with the requirements for
the degree of

MASTERS OF SCIENCE

In the subject

ENVIRONMENTAL MANAGEMENT

at the

University of South Africa

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10 November 2015

DECLARATION BY CANDIDATE

I hereby declare that this dissertation for the MSc Environmental Sciences at the University of South Africa is my own original work. I further declare that all sources cited or quoted are identified and acknowledged by means of a comprehensive list of references.

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Date

ABSTRACT

The aim of this study was to determine a carbon and water footprint for a beverage manufacturing company. The carbon footprint determination was conducted on Scope 1 and Scope 2. The water footprint was determined on the blue water and grey water. The beverage production volumes of the beverage manufacturing company were used to determine both the carbon and the water footprint.

The theoretical background to this study was based on both local and international beverage companies and the outcome for the carbon and water footprint was benchmarked against the local and international companies.

The objectives of this study were achieved by calculating a carbon and water footprint for the beverage company. The carbon footprint unit of measure is g CO_2e / litre produced and the water footprint is litre water/litre produced. The unit of measure for pollutant grey water footprint is measured in milligram.

Based on the results achieved in this study, recommendations for carbon and water footprint reductions were made to the beverage company. Reduction targets for production year 2020 were also recommended based on the implementation of the reduction plans.

DEDICATION

Dedicated to Anton, Adel, Chris and Berry.

ACKNOWLEDGEMENTS

I would like to acknowledge and express my appreciation and gratitude to:

- My supervisors, Prof K Mearns and Prof GH Stoffberg, for their assistance and guidance;
- The information scientists at Unisa for their assistance with the acquisition of literature material;
- The National Research Foundation for the student bursary for 2012 and 2013;
- The Beverage Manufacturing Company for the use of the secondary data;
- The participants in the interviews, particularly for their assistance in understanding and obtaining more secondary data;
- The Services Manager of the Beverage Manufacturing Company, for the assistance regarding data and explanation of equipment processes;
- The Beverage Industry Environmental Roundtable, Carbon Disclosure Project and the Global Carbon Exchange for assisting in obtaining literature and reference material;
- The language editor;
- Various people who assisted me in ensuring that the correct authors were cited – thank you for answering your emails;
- Promethium Carbon for guidance regarding carbon and water footprint calculations.

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LIST OF ABBREVIATIONS

BIER	Beverage Industry Environmental Roundtable
Brix	Degree sugar content
CDP	Carbon Disclosure Project
CIP	Cleaning in place
CO_2e	Carbon dioxide equivalent
CO_2e/kWh	Carbon dioxide equivalents per kilowatt hours
CF	Carbon footprint
COD	Chemical oxygen demand
Defra	Department of Environment, Food and Rural Affairs
ENEP	European Network of Environmental Professionals
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization
FDA	Food Drug Administration
GHG	Greenhouse gas
GHGP	Greenhouse Gas Protocol
GWP	Global warming potential
GWP100	Global Warming Potential calculated over 100 years
HDPE	High density polyethylene
HFCs	Hydrofluorocarbons
HSD	Honest significant difference
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JSE	Johannesburg Stock Exchange
kPa	Kilopascal
kWh	Kilowatt hours
LCA	Life Cycle Assessment
LDPE	Low density polyethylene
mg/Nm^3	Milligram per normal cubic meter
MW	Megawatt
PAS 2050	Publicly Available Specification 2050 (carbon footprint standard)

PET	Polyethylene terephthalate
PFCs	Perfluorocarbons
SAB	South African Breweries
SCADA	Supervisory control and data acquisition
UNEP	United Nations Environmental Programme
WEF	World Economic Form
WFD	Water Framework Directive
WFN	Water Footprint Network
WRC	Water Research Commission

CHAPTER ONE: INTRODUCTION AND BACKGROUND

1.1. INTRODUCTION

"The global environmental crisis is, as we say in Tennessee, real as rain, and I cannot stand the thought of leaving my children with a degraded earth and a diminished future … The hard truth is that our economic system is partially blind. The economy focuses more on the value added items, such as food, clothing, manufacturing goods, work and money whereby the environmental systems are not included in the value added item. The fresh and clean air that we breathe, the life of animals and our planet are some of the real value items that we and the economy are ignoring. This blindness is the driving force for the irrational decisions that we as humans and the economic system are making today" (Gore, 2008).

Climate change and freshwater scarcity are two critical environmental challenges faced by humankind and the earth's ecosystems alike (Millennium Ecosystem Assessment, 2005). The total available freshwater resource within South Africa is estimated to be 50 trillion litres. According to the Food and Agricultural Organization of the United Nations, approximately 25% of the total resources of the United States are withdrawn annually compared to a global average of just 9% (FAO, 2005). Clean air and fresh water are our scarcest and most precious resources. This study investigated the impact that carbonated beverages manufacturers have on these very important resources.

1.2. BACKGROUND ANALYSIS

Milk, coffee, tea, beer, wine and juice combined make up 28% of a consumer's total beverage consumption; together they represent 58% of the beverage industries' impact on climate change (Greenwich, 2010). According to the industry analysis, internationally the soft drink industry is dominated by three major brands, namely, Coca-Cola (with a global market share of around 50%), followed by PepsiCo (at about 21%) and Cadbury Schweppes (at 7%). Smaller companies such as the Cott Corporation and the National Beverage Company make up the balance. All of the above-mentioned companies make a sizable portion of their profits outside the United States (Deichert, Ellenbecker, Klehr, Pesarchick & Ziegler, 2006). Within the South African context, the Amalgamated Beverage Industries (ABI), the soft drink subsidiary of SABMiller, is the leading producer and distributor of Coca-Cola.

Beverage industries have conducted extensive carbon and water footprint research internationally, and have implemented various sustainability programmes (BIER, 2010). Carbon footprint calculations are tailored to the needs of any organisation and emissions within the organisation are classified as Scope 1, Scope 2 and Scope 3 (BSI, 2011). Direct company emissions (boilers, LPG gas, CO_2 gas) are Scope 1 emissions; Scope 2 emissions are indirect company emissions (e.g. purchased electricity) and Scope 3 emissions are other indirect company emissions (e.g. external manufacturing of packaging materials).

The water footprint of the beverage manufacturing process is classified as blue water and grey water footprint. The various water footprints are clearly defined by the water footprint assessment manual (Hoekstra, Chapagain, Aldaya & Mekonnen, 2011). The blue water footprint is an indicator of consumptive use, i.e. the use of fresh surface or groundwater. The grey water footprint indicates to which level freshwater is polluted as well as the quality of the effluent that companies are discharging and which are associated with the process (Hoekstra *et al.,* 2011).

Within the South African context, the soft drink market leaders have generally demonstrated greater attention to the carbon and water footprint, but this is not the case with the smaller beverage companies. This state of affairs is another indication of the importance of this study that seeks to give guidance to smaller beverage companies in reporting on their carbon and water footprint in the future.

1.3. RATIONALE

The focus of this study is on local beverage companies that have established an environmental management system (EMS) and that are certified against the international standard ISO 14001:2004 of the International Organization for Standardization (ISO) or companies that have established similar environmentally sustainability programmes. The ISO 14001:2004 EMS involves a structured, systematic way of identifying, addressing and correcting environmental problems, while integrating them into the general management system to ensure sustained improvement (ISO, 2004). Therefore, these companies need to have devised a basic monitoring and recording system for implementing emission reduction plans and identifying areas for environmental focus.

In this study, the carbon and water footprint calculation for a South African soft drink manufacturer was investigated together with possible future emission reduction options, based on the outcome of both the carbon and the water footprint at an operational level. By achieving the objectives set for this study the South African soft drink manufacturing sector will contribute to a better future, in terms of potentially saving environmental resources and reducing the social and economic impact of their activities. It is believed that the results of this study will provide a benchmark against which international soft drink companies whose information is publicly available can be measured.

1.4. RESEARCH DESCRIPTION

It has been observed that within the South African soft drink industry only one South African soft drink company has published their carbon and water footprint. If baseline footprints are set for all role players in the local soft drink market, the implementation of these carbon and water footprints could indicate the level of commitment that companies show to local consumers and influence possible future international investment within the industry. Capital expenditure is a key factor for companies to reduce carbon and water footprint, therefore the smaller companies find it difficult to achieve corporate footprint standards. The Amalgamated Beverage Industries (ABI) Midrand manufacturing and distribution unit invested R2.4 million in new equipment and systems to reduce waste water to achieve their benchmark to make more soft drinks with less water (SABMiller, 2007).

The South African Water Disclosure Report (Hanks, Bold, Dane & Hermanus, 2011) indicated that a significant number of large South African companies have yet to report on their water-related risks. The question is whether a business would continue to operate if water was suddenly not available to any part of the business, including their operations and supply chain. The 2030 Water Resource Group predicts a global water shortage of 40% by 2030 and for 20 years, it will cost between US$50 and US$600 billion to sustain the water demand (Hanks *et al*., 2011).

1.5. AIM AND OBJECTIVES

Based on the above-mentioned factors, the aim of this study was to conduct a carbon and a water footprint for a soft drink manufacturer in South Africa. The objectives were the following:

- Calculate the carbon footprint for Scope 1 and Scope 2 requirements.
- Conduct a water footprint assessment.
- Indicate possible opportunities for reduction for both the carbon and water footprints.

The Beverage Industry Environmental Roundtable (BIER) indicated that the beverage, Scope 1 and Scope 2 reporting includes processing and packaging operations and related activities that are under the operational control of the reporting company (BIER, 2010).

1.6. DESIGN AND METHODOLOGY

In conducting this study, the evaluation research method for quasi-experimental studies was followed. In quasi-experimental studies no random assignments are used; rather multiple measures are used. Mouton (2011) asserts that the main aim of outcome or product evaluation studies is to establish whether the intended (and unintended) outcomes of the programme have been realised. These typically include immediate or short-term outcomes, as well as long-term outcomes (or the “impact” of the programme). This research sought to indicate the carbon and water footprint calculation for a soft drink beverage manufacturer. As data collection and analysis for this study was both quantitative and qualitative, interviews (for qualitative data) and analysis were used as research techniques. These techniques are briefly discussed below.

1.6.1. INTERVIEWS (QUALITATIVE DATA)

Data were categorised as primary and secondary data: Primary data are defined as first-hand information collected either internally or from the supply chain. Secondary data are facts gathered from existing sources (BSI, 2011). Primary data for this study are classified as information retrieved via interviews and all other data are classified as secondary data.

Interviews were scheduled with the company under investigation that was ISO 14001:2004 certified or that had similar environmental monitoring systems in place. The interviews were conducted at various departmental levels within the company. It was important to understand the sustainability strategy and environmental aspects at various levels of the organisation. This interview process was also intended to verify the commitment from each departmental level of the organisation. Each interview was anonymous and participants had the right to discontinue the interview at any point or to refuse to participate in the interview. Questions asked were intended to yield the following information:

- Flow diagrams and operating procedures (inputs and outputs)
- Types of emission data collection (such as water, electricity and waste)
- Measuring units for the emission data (e.g. per kilogram or kilowatt)
- Reporting period for emission data (financial year of the company)

After a brief analysis of the interview data, preliminary delineation or system boundaries could be set.

1.6.2. ANALYSIS

Various sources including books, articles, journals, international standards, and the Internet were consulted to verify the data collected and identify the most suitable carbon and water footprint calculation method for the soft drink beverage industry. Computer software such as Microsoft Excel™ and the on-sequence systems of the Department for Environment, Food and Rural Affairs (Defra), and previously validated methods were used to analyse the emission data and to calculate the carbon footprint for Scope 1 and Scope 2. Hoekstra *et al.*'s (2011) water footprint assessment manual was also consulted. According to *The guide to PAS 2050:2011*, raw materials and energy processing are generally large contributors to emissions; therefore special attention needed to be paid to these two processes

(BSI, 2011). The outcome of the analysis will be shared with the businesses that made their emission data available. The company will receive the opportunity to be aided in identifying their hotspots and discover reduction opportunities that they may then implement.

1.7. CHAPTER BREAKDOWN

The introduction to the research problem is presented in Chapter 1. Based on the manufacturing company's objective, the study highlights the rationale for this current research, namely to calculate the carbon and water footprint calculations for one specific soft drink beverage manufacturer in South Africa. The research design of the study is an evaluation tool for quasi-experimental studies and is based on environmental sustainability. The carbon and water footprint calculations sought to identify areas for improvement as well as any future environmental sustainability programmes within the manufacturing company. An explanation is also presented of the research methodology that focuses on the collected data. The methods that were used for the interpretation of the assembled data are also included. The research flow diagram and chapter sequence is illustrated in Figure 1.1.

The literature review and the reported research compiled from international and local sources form the subject of Chapter 2. The focus in this chapter is previous and current studies conducted on the carbon footprint and the water footprint for the beverage industry. A considerable amount of work has been done internationally on carbon and water footprint calculations, but locally, within the beverage industry, only the wine industry and the South African soft drink market leader, has undertaken research on the carbon footprint. The possible gap between current methods used, results presented, and the interpretation of the footprint results are identified. The structure of this study followed the flow of the objectives of the study. Each objective is discussed and explained within a beverage manufacturing process.

The research design and methodology are explained in Chapter 3 which illustrates the research roadmap. An in-depth explanation is provided of the quantitative and qualitative data and how the data were statistically calculated to understand significant differences between both the carbon and the water footprint variables.

Indications of the process flow of a soft drink beverage manufacturing process and the explanation of each process are the subject of Chapter 4. The flow explanation continues in the translation of the raw materials and packaging materials into the final beverage through all the different processes. How these processes contribute to the carbon and water footprint of a soft drink manufacturing plant is also explained.

The production data of the manufacturing company for four years and the data results and analysis of the carbon and water footprint are discussed and interpreted in Chapter 5. The data were benchmarked internationally.

A discussion on environmental, social and economic points based on the carbon and the water footprints are in Chapter 6. Recommendations for the reduction of both the carbon and the water footprints are also suggested.

Chapter 7 synthesises the findings of the study and the recommendations for future research.

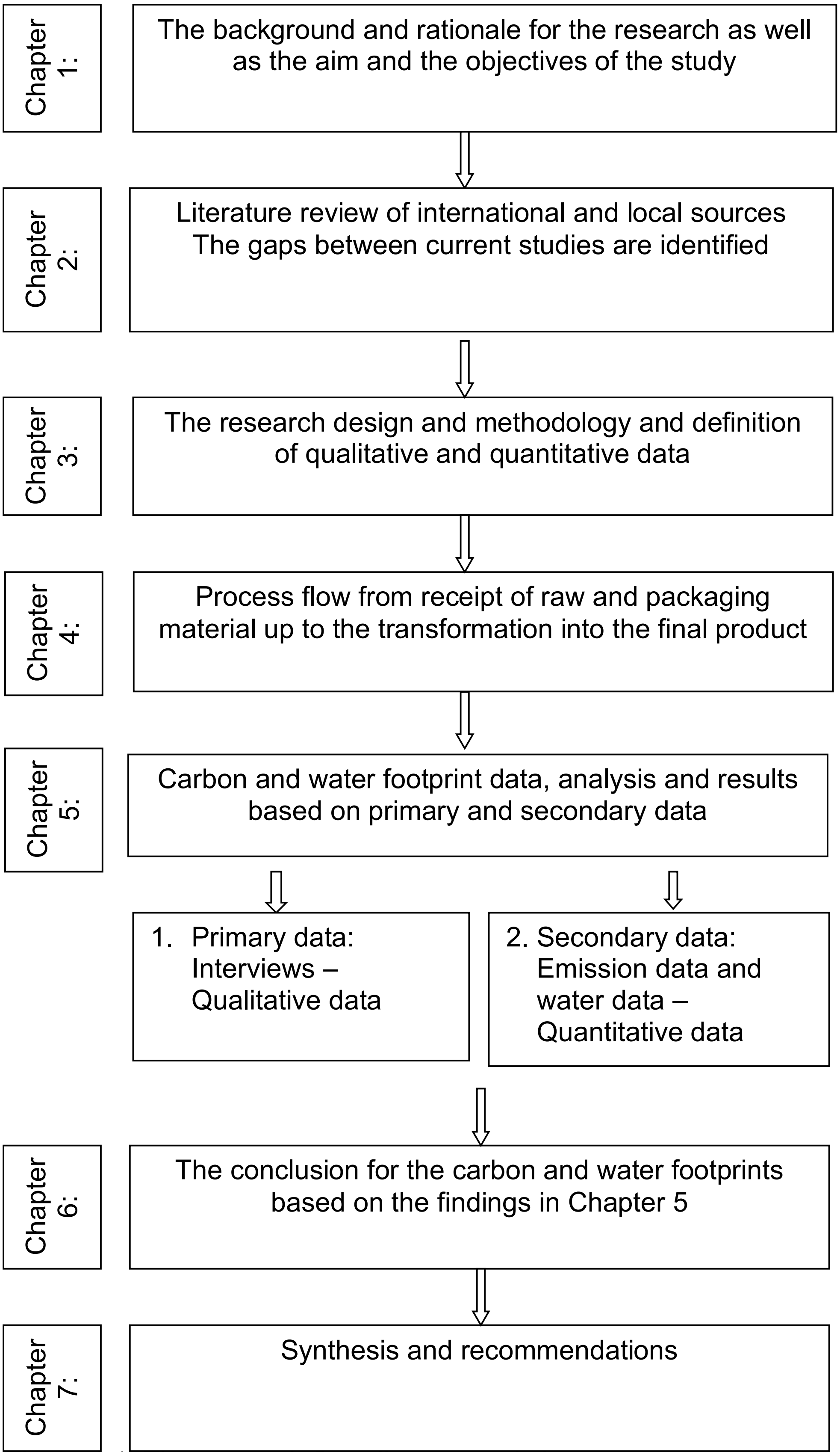


Figure 1.1: The research flow diagram and chapter sequence

1.8 SUMMARY

This chapter provides the background to the study and the rationale for the study. The first step toward reducing the ecological impact is to recognise that the environmental crisis is less of an environmental and technical problem than a behavioural and social one (Wackernagel & Rees, 1996).

CHAPTER TWO: LITERATURE REVIEW

2.1. INTRODUCTION

The increased levels of human consumption and the use of natural resources are putting a strain on the earth's ecosystem and there is wide agreement that the ecosystem will not be able to sustain these challenges (Wackernagel & Rees, 1996). This literature review describes various perspectives of carbon and water footprints. The difference between a carbon footprint and a water footprint is that carbon is measured at a global level and water is measured at a local level (Hastings & Pegram, 2012). Carbon and water footprint both address environmental issues but on different levels; the carbon footprint refers to climate change whereas the water footprint refers to freshwater scarcity (Ercin & Hoekstra, 2012). In the water–diamond paradox the question is asked whether diamonds are valued more highly than water (Young, 2005). Although its price is low, water has enormous value in terms of human use to because it is crucial to existence (Young, 2005).

2.2. CARBON FOOTPRINT

This study is focusing on the calculation of the Scope 1 and Scope 2 of the beverage manufacturing company. Scope 1 is the direct greenhouse gas emitted by the beverage manufacturing company and Scope 2 is the indirect greenhouse gas by purchasing electricity from an approved supplier.

2.2.1. CARBON FOOTPRINT DEFINITION

Carbon footprint can be defined as the amount of greenhouse gases emitted, expressed as carbon dioxide equivalent (CO_2e), relative to a unit of activity (BSI, 2011). In other words, the carbon footprint is used to quantify the contribution of various activities to climate change (Hoekstra, 2008). Direct and/or indirect total carbon dioxide emissions that are emitted during the life cycle of a product are defined as the carbon footprint (Wiedmann & Minx, 2007).

2.2.2. CLIMATE CHANGE

There is general agreement among individuals, government, and institutions that current production and consumption patterns might not be sustainable in the long term and that impacts on the environment must be reduced (Page, Ridoutt & Belloitt, 2011). Over the past 50-year period the burning of fossil fuels has led to an increase in global greenhouse gas (GHG) emissions. This situation is currently still the main contributor to the increase in global warming (Greenhouse Gas Protocol, 2012). The most prominent gases that increase global warming are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and nitrogen trifluoride (NF_3). The latter (nitrogen trifluoride) was added, at a latter stage, to the list of GHGs (Greenhouse Gas Protocol, 2012). Today carbon dioxide is the most problematic greenhouse gas because of the increased volumes emitted into the atmosphere (Svensson & Wagner, 2011).In the Carbon Disclosure Project (CDP) regarding accelerated solutions to climate change De Boer (2010, cited in Hanks, Bold, Dane & Hermanus, 2010a) noted that climate change is widely recognised as being one of the major threats facing the world at this time; its consequences go far beyond its impact on the environment alone. The question is no longer whether the focus must be placed on moving into a low-carbon future but, rather, how that will be achieved.

Increased climate change and the varying temperature throughout history have caused people to adjust to climate variability (IPCC, 2014). The current value of social, institutional and ecosystem measuring systems as well as the extent of adaption constraints to the measuring systems is on the increase (IPCC, 2014). To date, very little research has been conducted to determine the effects of the reduction implementation plans and most of the existing research focused on the impact of climate change and nature’s vulnerability to such change (IPCC, 2014). Various factors such as an increase in temperature and pollutant loading pose a higher risk to drinking water than to raw water due to climate change since these factors are projected to reduce raw water quality and not necessarily that of drinking water (IPCC, 2014). Managing the interactions between water, energy and land use will increase the efforts to adapt to climate change (IPCC, 2014). Examples of actions with co-benefits include the following (IPCC, 2014):

- ❖ Better and improved energy efficiency sources and the reduction of air pollutants
- ❖ Identification of recycling water systems to manage water consumption
- ❖ Sustainable agriculture and forestry
- ❖ Secure ecosystems

The managers of today must be encouraged to take an active interest in addressing the problem of climate change by demonstrating responsibility for its reduction. Businesses must take the lead and be part of the environmental solution. Each individual business model must focus on minimising their impact on the environment and have a vision of zero emissions and sustainable business operations (Svensson & Wagner, 2011). Programmes for environmental sustainability are an important corporate aspect for most organisations and it is vital to convince stakeholder audiences that the organisations' operations are legitimate to ensure compliance to local legal legislation (Hrasky, 2012).

Environmental resources are on the decrease due to the increase in the global human population, which is directly related to the increase in food production and food consumption (Myers & Kent, 2003). Natural resources have to be harvested faster as the world population increases (Wackernagel & Monfreda, 2004). The environmental footprint therefore represents the amount of resources required to produce food for consumption and to safeguard the environment (Ferng, 2001; Khan & Hanjra, 2009).

In a study conducted by the United States Environmental Protection Agency (EPA, 2013) the sectors that were found to be the largest contributors to greenhouse gas emissions (are presented in Figure 2.1):

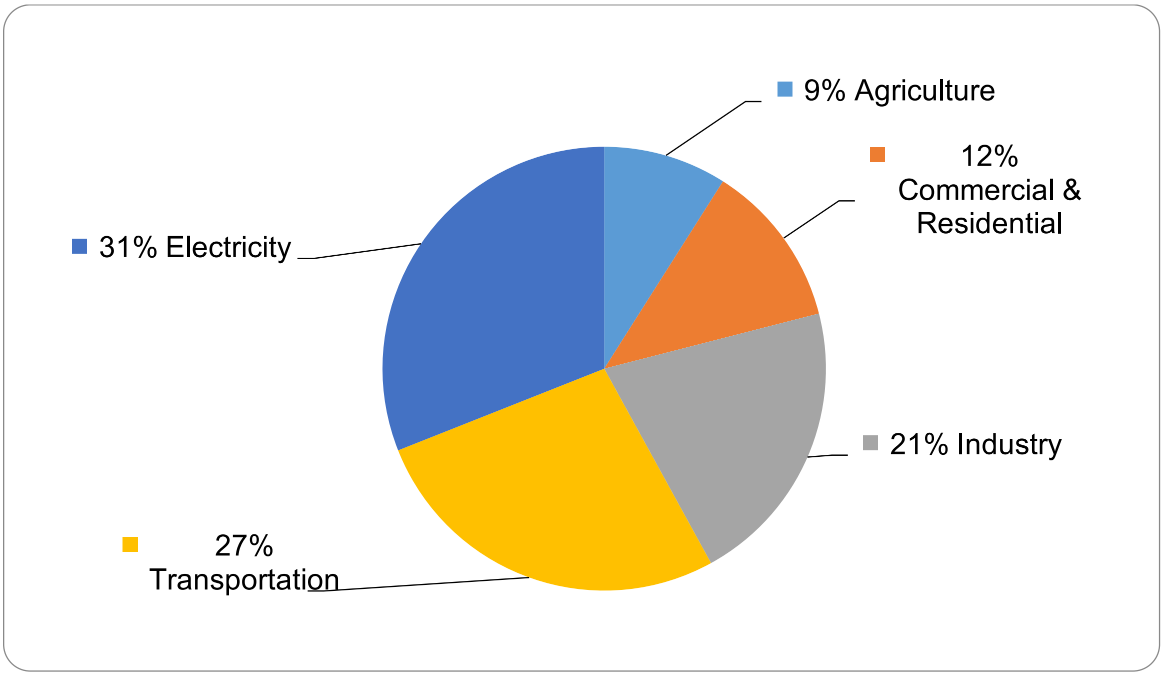


Figure 2.1: Greenhouse gas emissions (EPA, 2013)

2.2.3. CARBON DISCLOSURE PROJECT

The Carbon Disclosure Project (CDP) was established in 2000 to report on important global impacts on climate change and water consumption. The CDP has the largest primary data index related to corporate companies contribution to climate change worldwide (Basacik, 2014). In 2013, the CDP reported on over 4 000 organisations, including nearly 1 800 public responses to the CDP's climate change programme (Basacik, 2014). Corporate organisations across the world voluntarily disclose their greenhouse gas emissions, water use, target reduction, and performance improvement strategies through the CDP. These organisations decide on which emissions to report, depending on the strategy and circumstances within the organisation. The question is whether certain stakeholders or organisations are more carbon-intensive than other sectors (Hrasky, 2012).

The highest response, since 2009, to South Africa's first CDP was among the top Johannesburg Stock Exchange-listed companies. An increase from 87% to 94% in the assessment of Scope 1 and Scope 2 reporting has been noted since 2009, based on South African companies – of which 52 companies went public with their CDP emissions profiles in 2010 (Hanks, Bold, Dane & Hermanus, 2010b). The South African 100 CDP response rate in 2013 was 83%, which makes South Africa the second highest response region (Hanks, Baxter & Ashburner, 2013). Despite the fact that companies are reporting their emissions to the CDP, no significant reductions of emissions have been noted (Hanks *et al.,* 2013). Furthermore, variations in emissions within sectors are noted based on performance. The mineral and energy sectors reduced their emissions significantly based on Scope 1 and Scope 2 in 2012 while most of the other sectors showed an increase in emissions (Hanks *et al.,* 2013).

The South African government has committed itself to reducing the current carbon dioxide emissions by 34% by 2020, and 42% by 2050 (Hanks *et al.*, 2010b). In the 2010 CDP, South Africa's fourth CDP report generated a response rate of 74%, which is the fourth highest response rate internationally. Robbie Louw, Director of Promethium Carbon, noted at the Climate Change and Integrated Reporting conference that South Africa ranked first in the world regarding corporate reporting, according to the World Economic Forum publication on competitiveness that was released in 2012 (Vermeulen, 2013).

In 2010, the 31 companies that responded to the call indicated specific performance targets to greenhouse emission reductions, while 22 companies indicated their commitment to such reduction targets (Hanks *et al.*, 2010b). In 2013, 73% of the 300 companies that reports on the CDP, indicated a target to reduce emissions on an absolute or intensity basis (Fox, 2014). The companies that set targets achieved a 3% reduction in emissions against a 0.4% reduction in companies without reduction targets (Fox, 2014).

The CDP is developing a verification strategy, to be implemented during 2013–2018, that will stipulate requirements and ensure that companies have better knowledge of the CDP; thereby encouraging more companies to disclose their ratings on all three scopes (Hanks *et al.*, 2010b).

According to PAS 2050:2011 (BSI, 2011), Scope 1, Scope 2 and Scope 3 are defined as set out in Table 2.1.

Table 2.1: Scope definitions by PAS 2050:2011 (BSI, 2011)

Scope 1: Direct GHG emissions	**Scope 2: Indirect GHG emissions**	**Scope 3: Other indirect GHG emissions**
Greenhouse gas emissions from company's operations – example boilers, generators and compressors	Greenhouse gas resulting from generation of purchased electricity, heat or steam. This includes emissions from heating/cooling units, pollution control equipment, transportation of materials and waste.	Voluntarily reported information based on other functions of the value chain, for example third-party suppliers or distribution chain. It is very complex to determine Scope 3 because of limited information from the indirect sources. Examples of other indirect emissions are beverage ingredients, packaging materials, and transportation/distribution.

Operational boundaries distinguish between direct and indirect emissions. In a business, processes that are the sources of emissions are direct emissions. Indirect emissions are emissions that are caused by the activities of a business and the sources are controlled by another company (Ranganathan, Corbier, Bhatia, Schmitz, Gage & Oren, 2004). Companies in the service sector do indeed report their Scope 3 emissions, but there is a need to encourage larger companies to undertake Scope 3 assessments. The supply chain footprints are much larger than the operational footprints but this study was limited to Scope 1 and Scope 2 (BSI, 2011).

2.2.4. MANAGING AND CALCULATING A CARBON FOOTPRINT

Carbon footprint calculation methodologies are currently still under development, with 16 different methodologies available (Brenton, Edwards-Jones & Jensen, 2010). Usually the emission date is for one year (BSI, 2011) and all the greenhouse gases are quantified as a single measure and converted and reported as CO_2 equivalents (CO_2e). The PAS 2050:2011 (BSI, 2011), the Greenhouse Gas Protocol standard and ISO 14067 (ISO, 2013) assisted with the development of carbon foot printing from life cycle assessment (LCA) to the mainstream (Meinrenken, Kaufman, Ramesh & Lacker, 2012). There are two different types of approaches to report a carbon footprints, namely the control approach and the equity-shared approach (The Climate Registry, 2012). If the organisation wholly owns and controls all of the operations, then all emissions from each of the operations must be reported, as per organisational boundaries (The Climate

Registry, 2012). If the organisation owns a certain percentage shared in another company, for example franchises, then the equity-shared approach will be followed (The Climate Registry, 2012). The control approach was followed to calculate the carbon footprint for this current study because the manufacturing company wholly owned the controls of the operations.

The economic performance of business is often viewed together with social and environmental performances (Gerbens-Leenes, Moll & Schoot Uiterkamp, 2002). Carbon accounting and footprint focus on the impact of the organisation's activities on climate change, and do not necessarily include the social and economic performances (Brenton *et al.,* 2010). The typical carbon management programme is illustrated in Figure 2.2 and the steps to be followed are described below.

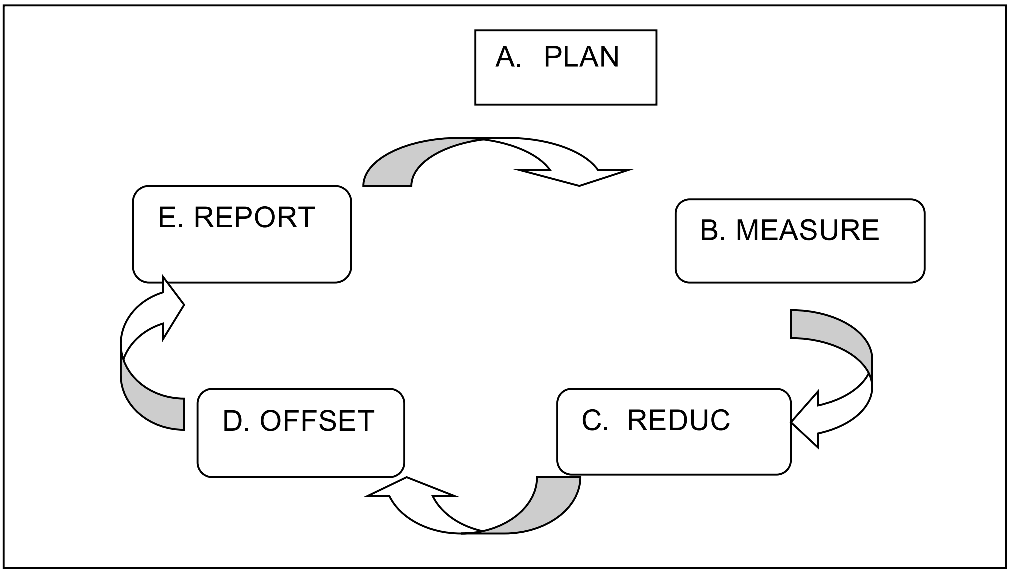


Figure 2.2: Carbon management programme (Abey, Burkett, Chan, Daniels & Williams, 2009)

a) Plan: Create a team and identify the greenhouse gases that have a significant effect on the business and the unit of measure to be applied based on the type of emission. Decisions need to be made to understand what methods can be put in place to measure emissions, and additional technologies or techniques are required to measure emissions (Hoffman, 2010). Thereafter identify the boundaries of the carbon management programme and which part of the business emissions are to be measured for Scope 1 and Scope 2 (Hoffman, 2010).

b.) Measure: Measure the emissions as accurately as possible, preferably for the financial year of the business and as per scope boundaries, as set out in the planning phase. In line with the measuring phase, reduction targets can be set based on the outcome of measuring results. Identify reduction targets in terms of a specific time frame, efficiency improvements, business strategy and goals achievable in line with new business opportunities (Hoffman, 2010).

c) Reduce: Reduce greenhouse gas emissions in the form of behavioural change or technological installation or implementation. An example of behavioural change is switching off lights to reduce electricity usage – a quick change. Technological change is more expensive and capital investment is normally required; for example, changing from a coal to a natural gas boiler. The main steps to reduce emissions, according to Hoffman (2010), are the following:

- ❖ Set reduction targets
- ❖ Draw up GHG emission reduction plans
- ❖ Evaluate, identify and implement the emission reduction plans
- ❖ Record reductions and cost saving on a regular basis
- ❖ Continue to make reductions, and look for new reduction opportunities
- ❖ Identify any "low-hanging" (behavioural changes) emission reduction opportunities and climate strategies to enhance top-sequence and bottom-sequence objectives

d) Offset: The aim for certain companies is to achieve zero GHG emissions within their operations, which is a reflection of carbon neutrality. A carbon neutral goal should include the following, as indicated by the United States Environmental Protection Agency (EPA, 2011):

- ❖ Implement an uncomplicated GHG inventory and identify at least one meaningful emission source to indicate the impact of the operations
- ❖ Identify reduction plans to reduce emissions
- ❖ Buy offsets to cover the remaining emissions from either direct or indirect emission sources

e.) Report: Report emissions over a specific timeframe considering the company's growth over that specific period. Determine the baseline year and the reporting measurement based on the company's objectives, for example per m^2, number of employees or number of production units produced; or litre total production. Verify results because mistakes do occur and recalculate if changes have occurred within the organisation, or in the calculation method, or if significant calculation errors have been identified. A significant threshold of 5% has been set by the GHG protocol but companies can set their own threshold to warrant recalculation.

The Global Reporting Initiative (GRI) sustainability guidelines have similar guidelines regarding the reporting of corporate sustainability factors (GRI, 2013):

- ❖ Identify the aspects and boundaries on which the organisation is going to report sustainability
- ❖ Prioritise the aspects to be measured and reported
- ❖ Validate the information that is measured
- ❖ Review the report after publication, regarding aspects measured

A base year must be set as a benchmark against which the organisation emissions are compared over time (The Climate Registry, 2012). Setting and updating a base year provides a standardised benchmark that reflects an organisation's evolving structure over time, allowing changes in the organisation's structure to be tracked in a meaningful fashion (The Climate Registry, 2012). Typical reasons for adjusting the base year are to reflect organisational changes such as mergers, acquisitions or divestments (The Climate Registry, 2012). The significance of recalculating the base year is defined as a cumulative change of 5% or larger in the organisation's total base year emissions (The Climate Registry, 2012).

Verification forms part of an environmental management programme to establish the reliability of the organisation's inventory programme. Verification programmes can identify improvement opportunities related to the current inventory system and provide a better understanding of the emissions being tracked (Hiraishi & Nyenzi, 2011).

2.2.5. POLLUTER PAYS PRINCIPLE

It was in the early seventies that the polluter pays principle was first implemented internationally (Wold, Gaines & Block, 2011). This principle calculates the cost of pollution prevention and introducing control measures to encourage the judicious use of scarce environmental resources; thereby avoiding distorted reporting on international trade and investment. The polluter should bear the expenses incurred to ensure that the environment will remain in an acceptable state (Wold *et al*., 2011). Failure to adapt to climate change will result in high risk both environmentally and economically (Vermeulen, 2013). According to Hoffman (2010), nearly 90% of the companies that participated in the research believed that government regulations regarding acting on climate change are too late and not properly managed; therefore the original reduction timeline of 2010 and 2015 could not be achieved.

The Australian carbon tax came into effect in July 2014. About 75 000 businesses were liable to pay the carbon tax during 2013–2014 in view of emitting more than 25 000 tonnes of carbon dioxide equivalent (CO_2e) during 2012-2013 or 2013–2014. From the 75 000 businesses a total of 1 000 paid carbon tax via the GHG levies and the rest paid through the fuel tax structure (Australian Government, Department of the Environment, 2014). Businesses must buy a permit for each tonne of carbon pollution and the cost is estimated at US$20 per permit. These permits must be submitted at the end of each tax year and any extra permits can be traded in the secondary markets (Carbon Planet, 2014).

The national government instigated polluter pays control measures in South Africa whereby companies were fined for polluting the environment. Some of these charges are based on stipulations in the National Environmental Management: Waste Act, No. 59 of 2008 (RSA, 2008) and the National Environmental Management: Air Quality Act, No. 39 of 2004 (RSA, 2014) of South Africa.

The Waste Management Act, No. 59 of 2008, defines various types of waste, such as the following:

- ❖ General waste: This does not cause a hazard or danger to human health or the environment (domestic waste and business waste)
- ❖ Hazardous waste: This poses harm to human health and environment.

The Waste Management Act, as part of the polluter pays principle, requires any person or organisation to avoid the causation of waste, and to reduce, re-use, recycle and recover waste. Listed activities defined in the Waste Management Act require the holder to apply for a waste licence. Some of the listed activities are the storage of waste, waste collection services and the transportation of waste. The content of the waste licence must specify the general conditions and the penalties related to not adhering to the conditions.

The specific manufacturing company on which the current study was conducted holds a valid waste licence due to the quantity of waste stored on the site. The daily waste generated (both domestic and industrial) is transported, recycled and re-used by third party companies.

Companies that exceed the atmospheric emissions, as per the listed activities in the Air Quality Act, No. 39 of 2004 (RSA, 2004), must establish their emissions substance or mixture of the substance, and must apply for an atmospheric emissions licence. The atmospheric emissions licence must specify the general conditions, including penalties for non-compliance, maximum allowed emissions amount, volume, emission rate or concentration of pollutants that may be released into the atmosphere.

As per the National Environmental Management Act (Act No. 107 of 1998) (RSA, 1998), a listed activity is an activity that would require environmental authority prior to commencement of that activity. Each listed activity identifies the potential impact of the activity and the operating conditions of the activity. Table 2.2 illustrates the requirements for the listed activity of gas combustion installations. The specific manufacturing company of this current study does not require an air emission licence because the in-house boiler is fed from natural gas.

Table 2.2: Listed activity: Gas combustion installations (RSA, 2004)

Description	Gas combustion (including gas turbines burning natural gas) used primarily for steam raising or electricity generation, except in reciprocating engines		
Application	All installations with design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used		
Substance or mixture of substances		Plant status	mg/Nm^3 under normal conditions of 3% O_2, 273 Kelvin and 101.3 kPa
Common name	Chemical symbol		
Particulate matter	NA	New	10
		Existing	10
Sulphur dioxide	SO_2	New	400
		Existing	500
Oxides of nitrogen	NO_x expressed as NO_2	New	50
		Existing	300

As per the South African Climate Change White Paper published in October 2011, a carbon budget approach will be designed for companies in specific sectors and/or sub-sectors. After adoption of the budget, a two-year timeline is set for sectors to comply with the climate change policy in relation to the budget. A future government aim is to introduce a compulsory reporting tool for companies that release more than 100 000 tCO_2e annually or that use electricity that is more than 100 000 tCO_2e. The proposed penalty of R120/t CO_2e could be implemented effectively from 2014 but was postponed to 2016 and beyond (RSA, 2011). In April 2013 the National Treasury, South Africa, indicated that carbon tax will only cover Scope 1 emissions resulting directly from fuel combustion and gasification, and from non-energy industrial processes. The tax threshold is set and the penalty of R120/t will go up with 10% each year till 2019 (Department of National Treasury, 2013).

Organisations currently have the opportunity to comment on the new proposed South African National Energy Act. Organisations that consume energy in excess of 400 terajoules (TJ) per annum must submit an energy management plan in line with ISO 50001 (Department of Energy, 2015). Organisations must identify areas of improvement, monitor and measure energy consumption and provide timelines for the implementation of their energy management plan.

2.2.5.1. PRODUCT AND PACKAGING CONTRIBUTION TO POLLUTER PAYS PRINCIPLE

A product's effect on the environment includes the total life cycle of the product, including processes of packaging manufacturing, distribution of material and product, use by the consumer and final disposal of the product and packaging (Zabaniotou & Kassidi, 2003). The most environmentally friendly disposal method is recycling of materials and the second is considered to be landfill (Pasqualino, Meneses & Castells, 2010).

The majority of branded goods manufacturers in the United States and the European Union moved to combine sustainability objectives and commitment with corporate social and environmental sustainability, such as the following (Coles & Kirwan, 2011):

- ❖ Reduction in packaging weight and volume
- ❖ Reusable packaging and refillable packaging
- ❖ Reduced emissions to air and water

Data released by European Metal Packaging (Empac) in 2011 indicated that the production of steel and aluminium cans over the past 20 years had increased by 57%. Within the same timeframe the total use of virgin metal was reduced by 20%, which resulted in a net CO_2 emissions reduction of 50% and a 60% energy reduction (Empac, 2011).

Glass is the least complicated recycled material based on the unlimited time taken for it to be crushed, melted and reformed without its structure deteriorating. Glass does not lose its quality features during the recycling process (Coles & Kirwan, 2011).

Sustainability benefits of using polyethylene terephthalate (PET) as packaging material are the reduction in packaging weight and other associated environmental benefits. These environmental benefits can be experienced within the production process, where less energy is required to produce the PET bottle in the blow moulding equipment, as well as in the supply chain where a lighter product is transported. PET and high density polyethylene (HDPE) milk bottles are items that are recycled the most within the plastic food container industry (Coles & Kirwan, 2011).

2.2.6. CARBON FOOTPRINT AND THE BEVERAGE INDUSTRY

Mineral waters and carbonated beverages originated in Europe during the 16th century. Apothecaries and chemists introduced flavoured soft drinks in the early 19th century by adding flavoured syrups to fountain-dispensed carbonated water. Today there are drinks of different levels of calorie, caffeine and non-caffeine, and various flavoured soft drinks (Morrow & Quinn, 2007).

Until 1948, soft drinks were packaged primarily in returnable glass bottles and in 1964, the non-returnable bottle made its appearance. Cans were introduced in the mid-1950s and PET in the late 1960s (Morrow & Quinn, 2007). The soft drink industry is improving its environmental footprint by increasing innovation and improving packaging. Consequently, soft drink products used 40% less packaging in 2003 than in 1990, while sales were up by 45% over the same period (Morrow & Quinn, 2007).

Leading International industries founded Beverage Industry Environmental Roundtable (BIER) in August 2006. Many of the largest beverage companies in the world, including Nestlé Waters, the Coca-Cola Company and PepsiCo, are part of BIER. The focus of BIER is to reduce energy consumption, water consumption and greenhouse gases across the entire value chain, including agriculture, transportation, packaging, and refrigeration (BIER, 2010).

BIER conducted research to determine the prime contributors of GHG emissions throughout the life cycle of a carbonated soft drink in Europe and North America. As pioneers of environmental safeguarding in the beverage industry, BIER embraces decision making processes through sharing data, knowledge, and conducting research. This approach will help to identify areas of concern within the beverage industry based on the type of emission sources and reduction guidelines (BIER, 2012a). The modelling process that was used for this research is illustrated in Table 2.3.

Table 2.3: Modelling processes (BIER, 2012a)

Category	Process	
Beverage ingredients	Water Sweetener	
Packaging material*	PET bottle Polypropylene cap HDPE label LPDE shrink wrap Wooden pallet	Aluminium can Fibreboard case LPDE shrink wrap Wood pallet
Production and warehousing	Electricity and natural gas Manufacturing waste disposal	
Transportation and distribution	Road Rail Ocean	
Retail and consumption	Electricity and natural gas (in-store refrigeration, lighting and climate control) Consumer refrigeration Consumer disposal	

*Multiple recycling methodologies were incorporated for packaging material.

The process established by BIER has led to a clearer understanding among industry leaders of what constitutes good practice and consistency reporting, by following the guide sequences provided by the PAS 2050:2011 and the Montreal Protocol. The Montreal Protocol is a leading success story in terms of international environmental treaties related to global coordination and operation. This protocol has been successful in decreasing or stabilising ozone-depleting substances (ODS) in the atmosphere and gives individual countries that signed the protocol the power to decide on how best to meet their reduction targets based on their domestic situation (McFarland, 2007).

There are various international standards available to guide organisations on how to report GHG. ISO 14064:2006 Part 1 is titled “Specifications with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals” (ISO, 2006). This part of the standard assists organisations in conducting GHG emission inventories and their approach to data collection, as well as consolidating and quantifying emissions. Part three of the standard, titled “Specifications with guidance for the validation and verification of greenhouse gas assertions”, explains the process for verification of GHG, including all inventories. Verifications can be done by a third party or by organisation’s internal auditor (ISO, 2006). ISO/TS 14067:2013, titled “Greenhouse gases: Carbon footprint of products, requirements and guide sequences for quantification and communication”, deals with current ISO standards and how to guide organisations regarding specific calculations for products (ISO, 2013).

2.2.7. CARBONATED SOFT DRINKS

A study to understanding the sustainability impacts from the UK beverage industry investigated the life cycle supply chain of several beverage products, such as carbonated drinks, beer, wine and bottled water. It was found that manufacturing and packaging were the main potential global warming contributors. Within the beverage industry, aluminium carbonated beverages contributed 80% of carbon emissions against 51% for beer carbon emissions. The total carbon footprint of a carbonated drink was reduced from 80% to 70% carbon emissions when aluminium was used as a substitute for PET packaging (Amienyo & Azapagic, 2011). The baseline results of the study conducted by BIER, indicated that the Europe 1.5 litre PET bottle contributed 34.8% of the total carbon footprint, with a total of 87g CO_2e (carbon dioxide equivalents). The sweetener contributed a total of 32.7%, which equates to 81.8g CO_2e. The North American 355 ml aluminium can contributed 68.9% and a total of 137.8g CO_2e; and the sweetener a total of 9.8% (19.6g CO2e). The total carbon footprint for the 1.5 litre PET Europe bottle was calculated to be 251g of CO_2e. The PET bottle contributed 35% of the total product carbon footprint, followed by sweetener of 33% and distribution transportation of 17%. The carbon footprint of the North American 355 ml aluminium can was 195g of CO_2e. The aluminium can packaging contributed 71% of the total product carbon footprint, sweeteners 10%, variations in electricity grid 10% and distribution transportation 9% (BIER, 2012a).

2.2.8. THE SOUTH AFRICAN FRUIT AND WINE INDUSTRY

The South African fruit and wine industry initiative was initiated through retail and consumer demand in the United Kingdom (UK) that request the quantification of the “carbon intensity” of the fresh fruit and wine products imported into the UK (Fuller, 2012). This guideline is intended for the fruit and wine industry to assist them in determining their carbon footprint and to explain the technical approach and parameters behind their GHG calculations (Fuller, 2012).

The South African wine industry is currently the only beverage industry in the country that has compiled and published its carbon footprint calculations. The South African Fruit and Wine Industry carbon calculator is a standard guideline for the measurement and reporting of GHG emissions for the industry. The guideline was developed in line with internationally recognised greenhouse gas accounting standards, such as the Greenhouse Gas Protocol, the ISO 14064:2006 (ISO, 2006), the PAS 2050:2011, the International Wine Carbon Calculator Protocol and the recently released Australian Wine Carbon Calculator (CCC, 2010).

Scope 1, Scope 2 and Scope 3 have been defined in the South African fruit and wine industry as follows:

- Scope 1: Fugitive emissions such as leaks of HFC-based refrigeration systems, CO_2 purchase and the use of CO_2 during wine fermentation, or diesel used within the processes
- Scope 2: Electricity, heating/cooling and steam purchased for the organisation's own consumption
- Scope 3: Emissions from a harvester that is not owned by the farm but is a contracted harvester

The industry calculates Scope 1 as total usage for the year and then allocates the usage per activity; for example, diesel usage for the transportation from the farm to the pack house. The last step is to allocate the usage per commodity; for example diesel usage per specific type of fruit and wine culture.

In a study conducted by BIER in 2012 to determine the carbon footprint for a 750 ml glass bottle manufactured in Europe and North America, it was found that the bottle manufactured in Europe had a total footprint of 1 286 g of CO_2e per 750 ml bottle. The highest emission contributor was the production of the glass bottle, a total of 45% of the total glass bottle footprint. The grape growing contributed 24%, energy used during the entire bottling process (10%) and packaging (9%). These processes accounted for 88% of the total footprint. The North American 750 ml glass bottle was calculated at 1 783g CO_2e. The glass bottle contributed 33%, followed by fermentation energy use (28%), grape growing (17%) and bottling, maturation and crushing energy use (12%). These processes accounted for 90% of the total footprint (BIER, 2012b). Cardboard packaging, transportation, warehousing, electricity, natural gas and maturation accounted for the other 10% of the total footprint (BIER, 2012b).

2.2.9. FOOD AND BEVERAGES

An ecological footprint that was conducted on the city of Cardiff to understand the environmental impacts and consumption level of Cardiff residents indicated that 68% of the footprint figure was related to food and drink (Collins, Flynn, Wiedmann & Barrett, 2006). This example is just another indication that the consumption of food and drinks has a considerable impact on the environment, which is directly affected by the manufacturing industries. Various international products carry the Carbon Trust approved labels. For example, the Walker 34.5g salt-and-vinegar crisps label states that 75g CO_2e had been emitted in the production and distribution; while the equivalent size pack of cheese-and-onion crisps states a 74g CO_2e rating (McKinnon, 2010).

Nestlé conducted research on the environmental impact of a consumer’s daily consumption based on water use, non-renewable energy use and climate change. Figure 2.3 provides an overview of the impact associated with each of the beverages (Dettling & Tatti, 2010).

With regard to the information on soda drinks (Figure 2.3 C1), climate change is the biggest contribution to soda drinks environmental impact, followed by energy and then water usage. The information provided above can be used as a benchmark for the reduction plans for the manufacturing company.

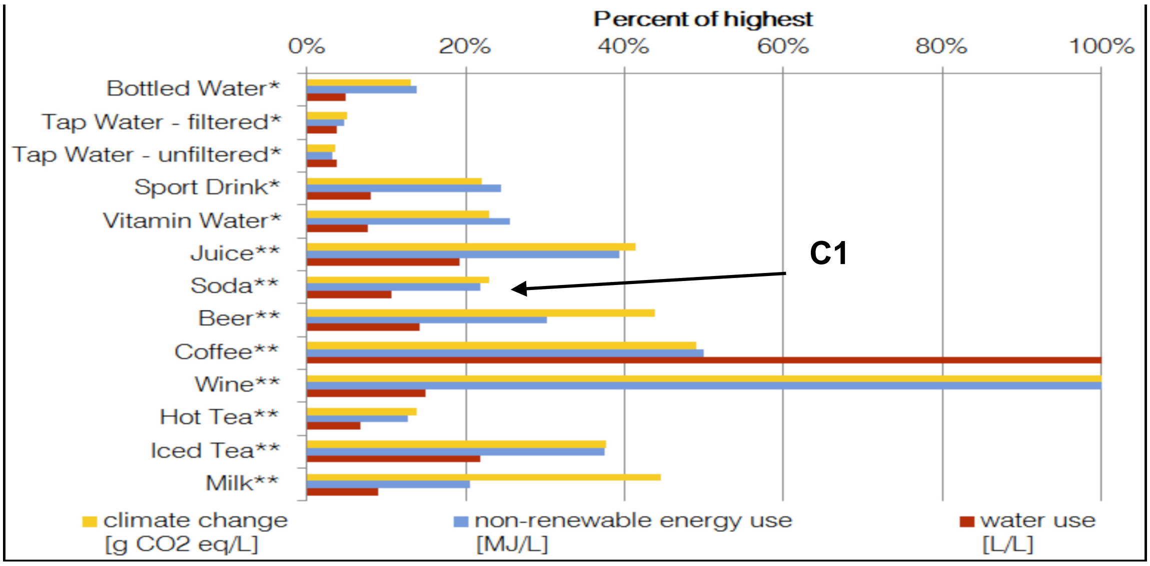


Figure 2.3: Comparison of beverages and the impact on climate change (Dettling & Tatti, 2010)

2.3. WATER FOOTPRINT

2.3.1. WATER FOOTPRINT DEFINITION

Living standards in developing countries have increased because of economic expansion, which had a direct effect on water resources due to the increase of production and goods consumption (Stoeglehner, Edwards, Daniels & Narodosklawsky, 2011). However around 1.2 billion people are still living in areas of physical water scarcity and a further 500 million people are living under conditions moving towards this situation (Molden, 2007). In line with increasing climate change, the stress on freshwater resources is also rising.

The water footprint idea was built on the concept “virtual water” that was introduced in the early 1990s by T Allan from the London Middle East Institute (Hoekstra & Chapagain, 2007). Virtual water is calculated by determining the sum of all the water used in the production chain to produce the specific product, service or goods (Hoekstra, 2008).

2.3.2. THE CONCEPT ‘WATER FOOTPRINT’

The concept ‘virtual water’ provides a perspective on water scarcity and not necessarily the environmental impacts. Virtual water focuses on the amount of water that is representative of the product produced. The term ‘water footprint’ includes the total water and the type (green, blue, grey), as well as the source of water used to produce the product or service. The water footprint of a product is a multidimensional indicator, where virtual water refers to volume alone (Hoekstra *et al*., 2011). The concept of water footprint was introduced in 2002 and it refers to both the direct and indirect water use of a consumer or producer (UNEP, 2012). The virtual water chain is represented in Figure 2.4.

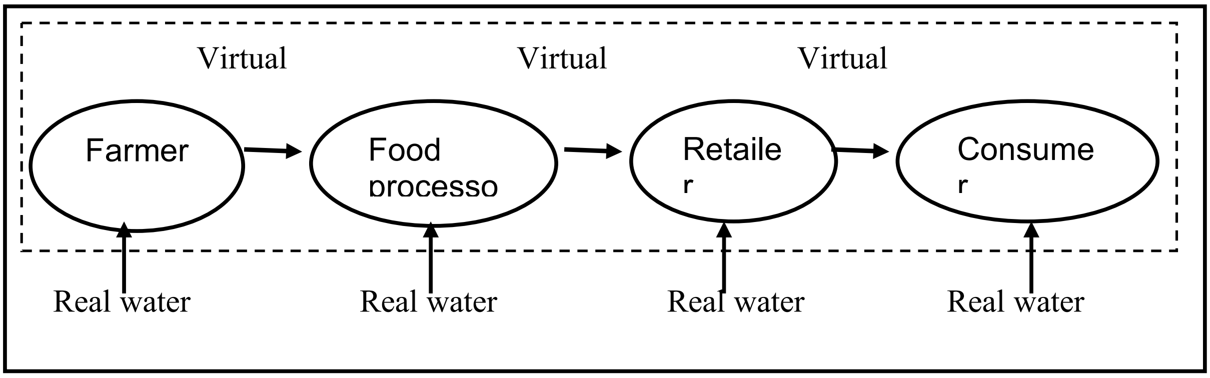


Figure 2.4: Virtual water chain (Hoekstra*,* 2008)

The virtual water concept of a food processor is the water used from farmer to the end consumer. The water footprint concept shown in Figure 2.5 is more complex than what is shown in Figure 2.4. The footprint is broken down into building blocks and each building block is individually calculated to determine the specific footprint required as illustrated in Figure 2.5

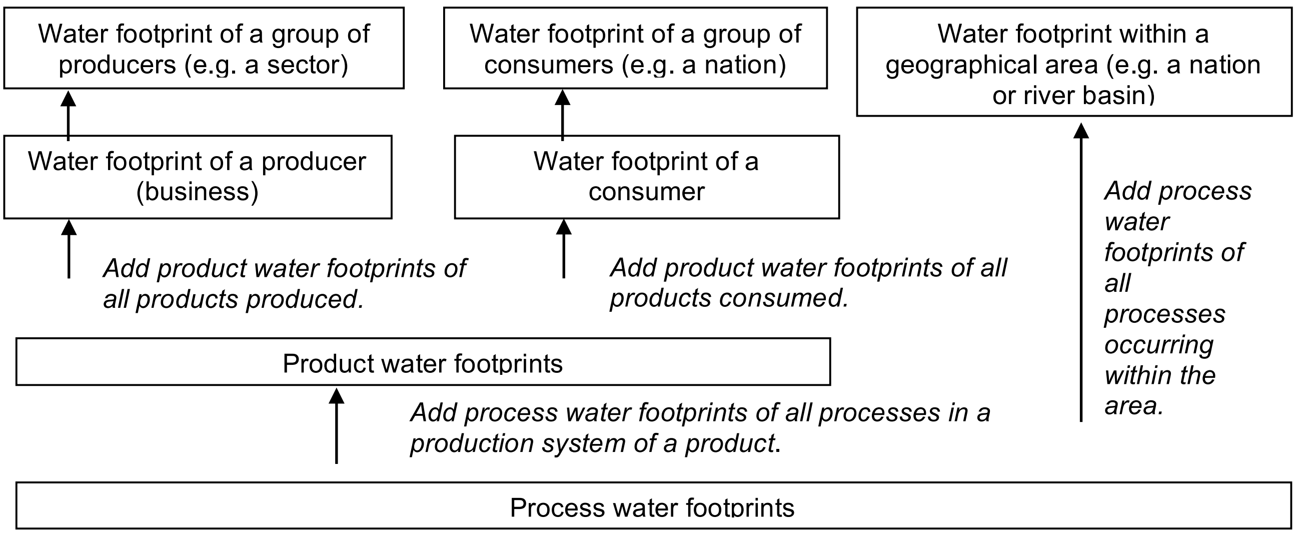


Figure 2.5: Process water footprints as the basic building block for all other water footprints (Hoekstra *et al.,* 2011).

Figure 2.5 indicates that the building block for any footprint starts with the water footprint of a process. Identifying the process water footprint, the product water footprint can be calculated, which is directly linked to the business that is producing the product. The consumer footprint is calculated by understanding all the types of products that the consumer consumes. The next level water footprint is based on the business or consumer water footprint. National footprints are based on all the products that a consumer consumes or the products the country produce (Hoekstra *et al.,* 2011).

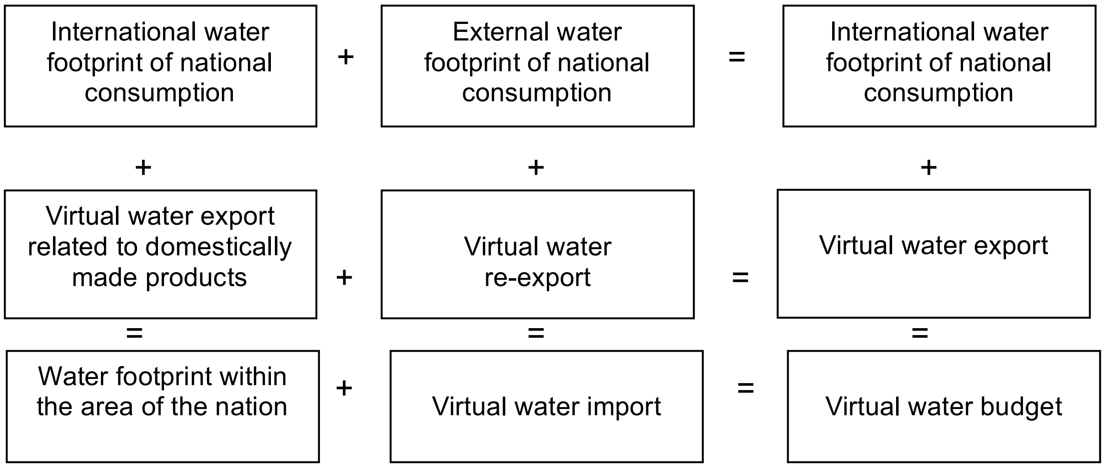


Figure 2.6: Framework for national water footprint accounting to determine the water footprint for a nation as well as the data that is required for each calculation. (Hoekstra *et al.*, 2011)

Hoekstra *et al.* (2011) define the above methodologies as follows:

- ❖ Water footprint of a nation: This is all the domestic water that is needed to produce the goods and services for the people of the nation.
- ❖ External water footprint of a nation: These are the goods that are imported into the country. It is the volume of water used to produce the goods or services from the export country.
- ❖ Virtual water export related to domestically made products: This is water that is needed to produce the goods or services within the same country but in different provinces in the country.
- ❖ Virtual water re-export: This refers to exported water of domestic origin and the re-exported water of foreign origin.

- ❖ Water footprint within the area of the nation: This is the water from a specific catchment area, river basin or municipality that is used to produce the goods and services.

Virtual water import: The virtual water import into a geographical area is the volume of water associated with the import of goods or service into the area.
The Water Research Commission (WRC) of South Africa has launched a project to determine the contribution of water footprint calculation to ensure the sustainable management of water in South Africa. The project is aimed primarily at the industrial sector and explores links between water and energy and the concept of water offsetting (Hastings & Pegram, 2012).

The concept 'water footprint' must be seen against the background of global environmental constraints and the depletion of fresh water. It is predicted that water resource depletion will become the focus point of discussions regarding sustainability (Page *et al*., 2011). Companies can disclose their water footprint, which will give them an understanding regarding the risks of the decisions to be made related to water planning and sustainability. Water footprint tools and methodologies are still within developmental stages and various questions still remain regarding water footprint calculations (Hastings & Pegram, 2012).

In the Water Framework Directive, which is part of the European Union legislation, it is noted that the 2015 objectives of good ecological status will hardly be achievable due to old and emerging challenges related to both water quality and water quantity (EEA, 2010). The United Nations Environmental Programme (UNEP) recently commissioned a report (UNEP report) in conjunction with the CEO water mandate (UN Global Compact, 2014) to identify obstacles and potential solutions, which would advance global water stewardship efforts (BIER, 2011).

The UNEP report identified six key areas in which water accounting practices can be improved through emerging practices:

1. Agree and define the concept "water footprint".
2. Design a measuring tool for individual watershed and communities.
3. Share and compute water information within industries.

4. Improve the collection of primary data.
5. Motivate suppliers to reduce their water footprint.
6. Improve effluent discharge quantity and quality.

Organisations must aim to be “water neutral” and therefore they must comply with two requirements, namely to reduce the existing water footprint and to establish investment projects to ensure the sustainability of water (Hoekstra, 2008). Sustainable corporate accounting should include the principles of water footprint to increase their market share. Water supply will be affected most by climate change due to water scarcity and water availability.

The concept of water footprint has evolved independently from Life cycle analysis (LCA) and has to date focused on the quantity of water use. The difference between the two concepts is that LCA is time and location independent and water footprint is seasonal and location dependent (Jeswani & Azapagic, 2011). LCA has informed the development of footprints with its “cradle-to-grave” approach for considering different types of environmental impacts (Hastings & Pegram, 2012).

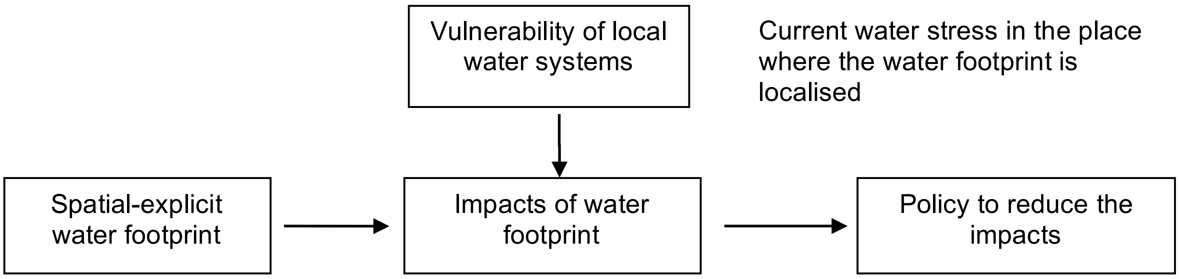
The unit of measurement for a product water footprint is fresh water used per unit of product. In most cases the supply chain water footprint is larger than the operational water footprint (Hoekstra, 2008). Unlike carbon, the metrics for water must account for the location and timing of consumption and the discharge. It must be taken into account that the one water catchment does not reduce or offset the impacts of a different catchment (Hoekstra, 2008).

In 2014, a working group of BIER reviewed the existing concepts for water measurement. It was found that some of the current concepts are too academic, indicate a lack of transparency, too subjective and have a singular focus (Barbieri, Martin & Battjes, 2015). There is limited current quantitative data for the food and drink industry and they are expressed in different ways, which makes comparison between results problematic. Water is measured as either total water consumption per tonne of product or litre of product produced (Valta, Moustakas, Sotiropoulos, Orli, Angeli, Malamis, Haralambous*,* 2013). This ISO ISO 14046:2015 standard: *Water Footprint a growing demand for assessing and reporting water footprints* provides transparency, consistency, reproducibility and credibility for assessing and reporting the water footprint for products and processes of organisations (ISO, 2015).

2.3.3. METHODOLOGIES

2.3.3.1. THE HOESTRATA, CHAPAGAIN, ALDAYA AND MEKONNEN APPROACH (2011)

A water footprint for a process, product, business or consumer can be determined by making use of various different calculations methods (Hoekstra *et al.,* 2011) it is essential that all the different water user groups reduce their water footprint. Water neutrality refers to reducing a water footprint and offsetting the impacts of water footprints as shown in Figure 2.6 (Hoekstra, 2008).



Water footprint of:	Types of negative externalities:	Water neutral:
A product An individual Externalities A community A business	Economic Social Environment	Reduce and offset the negative

Figure 2.7: Impacts of water footprints (Hoekstra, 2008)

A business water footprint is the sum of the supply chain and the water used in the operational process. The operational (direct) water footprint of a business is the total volume of fresh water used and the water that forms part of the effluent system within its operations. The supply chain (indirect) water footprint is the total volume of fresh water used or water that is polluted to produce the specific goods and/or services that are seen as the inputs of production of the business (Hoekstra, Chapagain, Aldaya & Mekonnen*,* 2009).

Various footprints are calculated in application of the Hoekstra methodology. The water footprint depends on the type of industry, and is calculated by determining the water footprint for blue, green and grey water (Hoekstra *et al.,* 2011).

Table 2.4: Definitions of the different types of water as per the European network of environmental professionals (ENEP, 2012)

Green water	Blue water	Grey water
The green water footprint is the rainwater consumed by plants.	The blue water footprint refers to the volume of surface and groundwater consumed to produce a product.	Grey water is the volume of water needed to dilute a certain amount of pollution such that it meets ambient water quality standards.

The green water footprint is the amount of rainwater that is consumed within a specific process and that is not part of run-off water (Hoekstra *et al.,* 2011). The green water footprint is more applicable in the context of agriculture than in the context of beverages because the beverage manufacturing facility under investigation does not harvest rainwater to be re-used within the process. Therefore, there is no green water footprint for the beverage manufacturing company. Green water is water that is trapped in soil or temporarily stays on top of the soil until it is consumed by plants. This is particularly relevant for agricultural and forestry products. Green water footprint is calculated as:

[1] $WF_{proc.green}$ = GreenWaterEvaporation + GreenWaterIncorporation (volume/time)

For a nation, blue water is the total volume of fresh water that is abstracted from rivers, lakes and aquifers. Another definition of blue water footprint is the sustainability of groundwater abstraction and use (Coles & Kirwan, 2011). The blue water footprint within a beverage manufacturing company is the total amount of incoming water that is used within the entire production process. The blue water footprint for a nation is calculated by determining the amount of water that evaporates, the water that is part of the system, and the water that does not return to the same catchment area or within the same time frame. The unit of measurement is either per day, per month or per year. The blue water footprint for a nation is calculated as follows:

[2] $WF_{proc.blue}$ = BlueWaterEvaporation + BlueWaterIncorporation + Lost ReturnFlow (volume/time)

Grey water, in the case of a nation, is determined based on the pollutants in the water and the volume of fresh water that is needed to dilute the pollutant to ensure the quality of the water is compliant to regulatory requirements (Jeswani & Azapagic, 2011). Within the beverage manufacturing company under investigation the measurement of grey water is based on the total amount of water that is discharged in the effluent system. The grey water footprint of a nation is determined by the concentration of pollutant in the water. It is the total amount of fresh water that is required to dilute the pollutants in the grey water and to ensure that the concentration is of such a percentage that the water can be put back into rivers, lakes or dams. The grey water footprint is calculated as follows:

[3] $WF_{proc.grey} = L / (c_{max} - c_{nat})$ (volume/time)

L = pollutant load

c_{max} *= the maximum acceptable concentration in mass/volume*

c_{nat} *= the natural concentration in the receiving water body in mass/volume*

The product water footprint for this study was determined by defining the total volume of water that is required either directly and indirectly to produce a litre of product on the manufacturing site. It was determined by identifying all water consumption and pollution within all the production steps (Hoekstra *et al.,* 2011). The beverage manufacturing company classified the different types of water as total incoming water, treated water and untreated water. The total incoming water was all the water that was received from the municipality. Some of the total incoming water was diverted to the water treatment plant and the treated water was the water that was used to manufacture the product. The untreated water was water that was used within the utilities of the beverage company. The water footprint of a product consists of the sequential process steps within the product that is produced. The water footprint for a product produced at the beverage manufacturing company under study was calculated by determining the total amount of water used within the processed divided by the amount of product produced.

[4] Blue water footprint = $\frac{\textit{Total water used within all processes}}{\textit{Total litres of product produced}}$

The grey water footprint for the beverage manufacturing company under study was calculated by determining the total litres of effluent against the total litres of production:

[5] Grey water footprint = $\frac{\textit{Total litres effluent within all processes}}{\textit{Total litres of product produced}}$

The pollutant load per specific parameter was also determined as per the nation's grey water footprint methodology as indicated above (see [3] above). The reason for this calculation was to give the beverage company guidance for possible future reduction plans for the effluent water system.

2.3.3.2 THE MILA i CANALS, CHENOWETH, CHAPAGAIN, ORR, ANTON AND CLIFT APPROACH

This approach determines the water use at a river basin that is the total use at the source and also the type of water used. It follows the Hoekstra (2008) approach by also determining the blue water and green water footprint. The evaporated and non-evaporated water use is identified, whereby the non-evaporated water is either returned back to the freshwater source or is made available for further use. The evaporated water is the amount of water lost through an evaporation process specific to the process (Jeswani & Azapagic, 2011).

2.3.3.3 THE PHISTER AND RIDOUTT APPROACH

This approach considers water usage on a smaller scale than the Mila i Canals *et al.* approach, taking watershed as the area of focus, which is based on blue water only. This method defines three ways of water use: in-stream water use, consumption (where the water is no longer available in the watershed) and water-quality degradation (where the water is still available after use but with diminished quality). The main difference between the Mila i Canals *et al.* approach and the Phister and Ridoutt approach is that the water discharged to another watershed is treated as consumed; while the Mila i Canals *et al.* approach considers the water discharged to any freshwater source as a non-evaporative use (Jeswani & Azapagic, 2011).

2.3.4. WATER DISCLOSURE

When companies disclose their water consumption reports the following risk categories are used (Adrio, 2012):

- ❖ Physical risk – This risk is directly related to the operations and the supply chain. It is defined as the changes in water quantity or quality
- ❖ Reputational risk – In this case the company might have possible conflicts in relation to the public and the disclosure can cause damage to a company's brand image
- ❖ Regulatory risk – Countries have various regulatory requirements related to water use. Regulatory risk also poses a threat to the company's image when regulations are not adhered to
- ❖ Litigation risk – This is a risk related to lawsuits or other legal actions arising from the company's impacts on water levels and water quality

2.3.5. WATER NEUTRALITY

Water neutrality is achieved when the water footprint is reduced as much as possible, while offsetting the negative areas of the remaining water footprint (Hoekstra, 2008). Achieving water neutrality does not mean that the water usage is reduced to zero but rather that the negative economic, social, and environmental impacts are reduced as much as is possible (Hoekstra, 2008).

2.3.6. POLLUTER-PAYS PRINCIPLE

The polluter-pays principle requires that the cost of pollution prevention, control and reduction measures should be borne by the polluter (Hirji, Johnson, Maro & Chiuta, 2002). For many companies fresh water is the basic ingredient of their product and/or the service that they deliver. Many of these companies fail to manage and reduce water usage by preventing unnecessary use of fresh water for their operations. This can increase the business threat of financial risk and damage to corporate image (Hoekstra, 2008). The total environmental impact of packaging is far less than the impacts of food and drink waste, due to the outputs involved in food and drink manufacturing (Coles & Kirwan, 2011). It is generally noted that where the demand for water is relatively low in water-rich countries the water laws are simple and not very strictly enforced as opposed to water-scarce areas, where the water laws are strictly enforced and more elaborate management systems have evolved (Young, 2005).

Over-abstraction of water resources is one of the major factors threatening the sustainability of southern Africa's water resources (Hirji *et al.*, 2002). The National Water Act, No. 36 of 1998 of South Africa, set out basic requirements for the basic human needs of present and future generations: the need to protect water resources, the need to share some water resources with other countries and the need to promote social and economic development. The activities that are not listed in Schedule 1 of the Act must be licensed. The Act defines water use as taking water, storing water, activities that reduce flow, waste discharges and disposals, altering a water course, and removing water found underground for certain purposes. Based on the above listed activities, the specific manufacturing company that was the subject of the current study was in a possession of a discharging permit for the discharging of industrial waste water into a water system resource. Record-keeping and disclosure of the information to the local municipality was essential.

The South African National Water Act, No. 36 of 1998 was hailed by the international water community as one of the most progressive pieces of water legislation in the world; yet, 15 years later the implementation of the Act was been only partially successful (Schreiner, 2013). To address the issue of capacity, participatory water management should result not only in the consultation with stakeholders but in partnerships with key players from the local to the national level. Such key players include community-based organisations, water user associations, catchment management forums, non-government organisations and the private sector (Schreiner, 2013). Manufacturing businesses tend to have access to low cost water directly from surface or groundwater sources or from public utilities (Young, 2005). In resource allocation decisions, cost of capital, labour, energy and other raw materials tends to overshadow the cost of water even where large amounts of water are used (Young, 2005).

The South African Department of Water Affairs (DWA) initiated a rainwater harvesting programme mainly for rural households and other institutions such as medical clinics. Bigger organisations must follow the initiative by harvesting rain water for the use of general cleaning purposes (DWA, 2013). The implementation of water re-use guidelines is also in play and the guidelines indicate the choice of waste water treatment technology and also the type of water quality achieved after treatment. The department will still review the water-related laws for the re-use of waste water, regarding the discharge level back into the water system and the effect on the downstream users (DWA, 2013).

2.3.7. NATIONAL AND INTERNATIONAL INDUSTRIES

It is estimated that over ZAR570 billion is needed for the maintenance and expansion of South Africa’s water infrastructure (Zhuwakinyu, 2013). In 2013, a South African newspaper (Rapport) revealed that about 14 of the biggest towns in the country did not have enough water or lacked a proper water and effluent purification system (Kitshoff, 2013). Eybers (2013) cautions that the major cities in South Africa will face a serious water scarcity by 2020. The poor quality of water in South Africa limits the utilisation value and adds an economic burden on society through both the primary treatment cost and the secondary impacts on the economy (Claassen, 2010). The cost of treating water for human consumption increases as our water resources become more polluted. The challenge for South Africa lies in the efficient and balanced use of water, together with other natural resources, to create an environment in which social and economic well–being are balanced (Claassen, 2010).

The sustainable use of water resources presents challenges in terms of the production of goods that are high in water-intensive processes, such as food and beverages. The level of sustainable water use includes the technological improvements as well as the attitude of management towards water resources (Ene, Teodosiu, Robu & Volf, 2012). The environmental footprint defines the land

and water that are needed for the production of food for consumption and to maintain the quality of environment (Ferng, 2001; Khan & Hanjra, 2009).

An assessment has indicated a 73% water scarcity as an important business risk to some food and beverage companies and hence the importance of setting targets to reduce operational water use. Two of the largest soft drink companies in the world (Coca-Cola and PepsiCo) set a target to reduce their water consumption by 20% per unit of production by the end of 2012 and 2015 (Moffat, Scotnicki, Berwick, Lang, Ramani, Casey, Barton, Crawford & Sen, 2013).

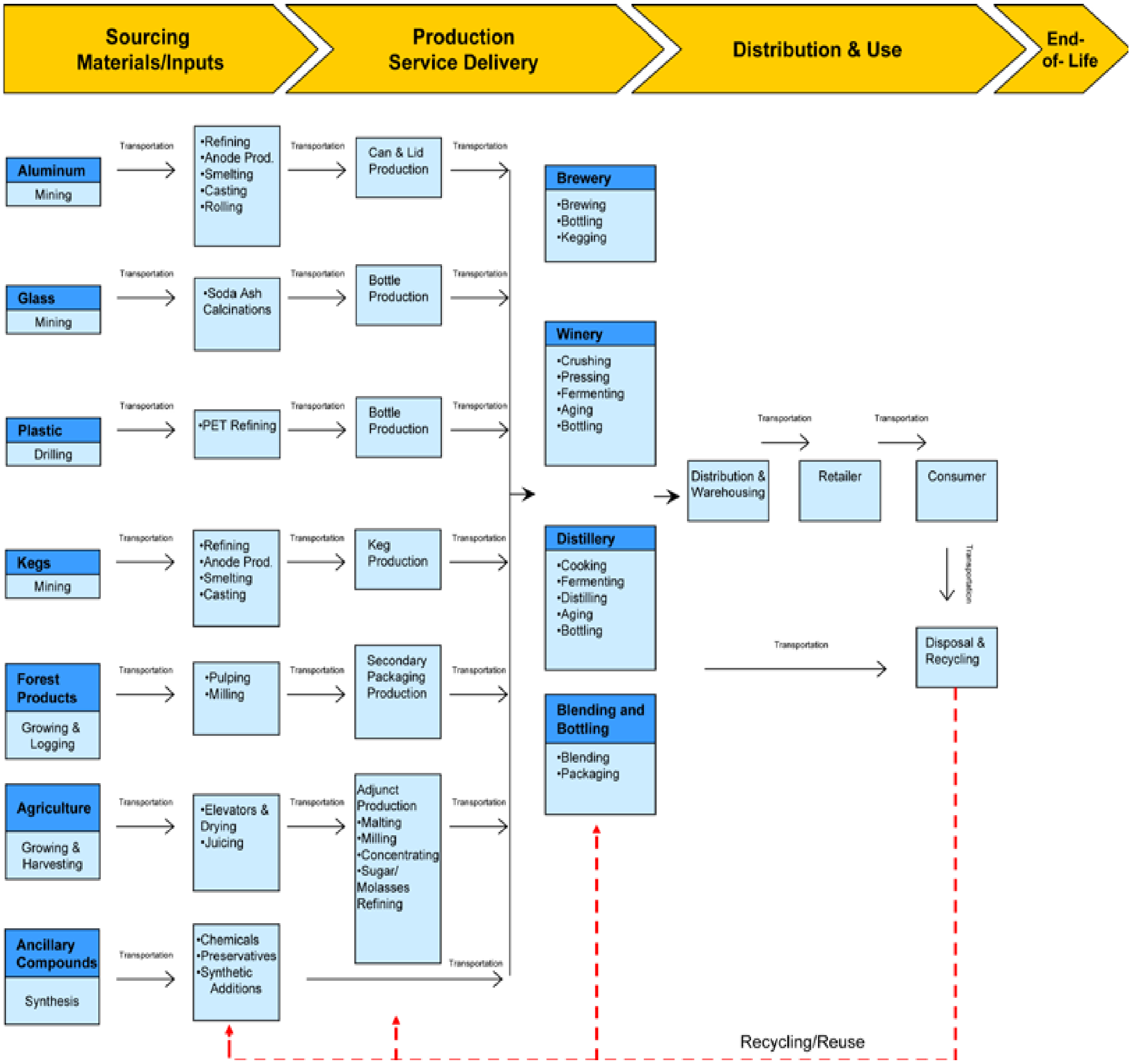


Figure 2.8: The major activities within a beverage product water footprint (BIER, 2011)

The water footprint of a final product is the total of the water footprints of the various process steps relevant in the production of the product, as illustrated in Figure 2.9 (Hoekstra *et al.,* 2011). However the water footprint of a producer or a business is equal to the sum of the water footprints of the products that the producer or business manufactures (Hoekstra *et al.,* 2011). Figure 2.9 illustrates the basic building blocks.

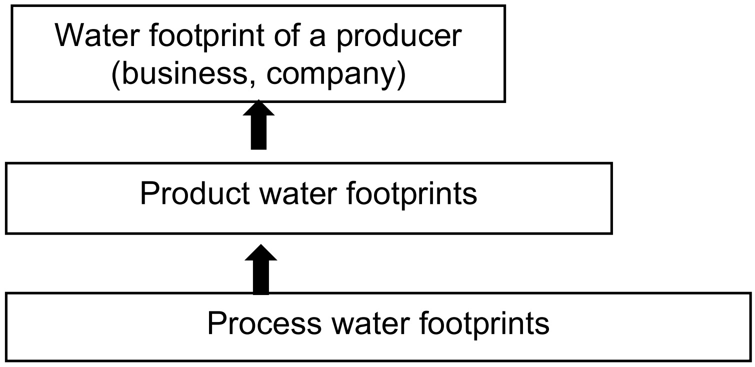


Figure 2.9: Process water footprints as the basic building blocks for all other water footprints (Hoekstra *et al.,* 2011)

Figure 2.9 illustrates that an organisation or business must understand their process water footprint first before it can improve the product and/or business water footprint.

2.3.8. BOTTLED SUGAR WATER

A water footprint study was published in 2010 based on a hypothetical 0.5 lt PET bottle of carbonated beverage made from different types of sugar. The highest water footprint of 309 l/l (litre water used / litre production) was noted for 0.5 litre when the sugar originated from cane sugar produced in Cuba, while the lowest water footprint (169 l/l) was achieved when beet sugar, from the Netherlands were used. The largest impact of the water footprint of the beverage is related to the sugar ingredient (Ercin, Aldaya & Hoekstra, 2010). It is also noted that three litres of water is require to produce 1 litre of carbonated soda and 250 litres of water to produce the sugar to flavour a carbonated drink (Ionescu-Somers & Steger, 2008).

2.3.9. COFFEE AND TEA

A study conducted in 2007 on the water footprint of coffee and tea consumption in the Netherlands showed that in total the world population requires about 140 billion cubic metres of water per year to drink coffee and tea. The virtual water content of coffee or tea is the volume of water required to produce one cubic ton of coffee or tea. Based on the average of 7 g of roasted coffee per cup, the standard cup of coffee in the Netherlands requires about 140 lt of water. Based on 3 g of processed tea per cup, the standard cup of tea requires about 34 lt of water (Chapagain & Hoekstra, 2007). It is evident that a it requires about four times more water to produce a cup of coffee compared to a cup of tea.

2.3.10. WINE INDUSTRY

Romania is one of the 15 global wine producers and the sixth largest wine producer in Europe. A study was conducted on a 750 ml bottle of wine in Romanian plant (Popa, 2009).The findings of the Romanian study indicate that almost 99% of the total water footprint relates to the supply-chain water use. The total of green water was 82%, 3% blue water and 15% grey water. According to the outcomes of the Romanian wine plant study, the waste water consists mainly of high concentrations of organic matter and nutrients and it has high acidity due to the seasonal nature of wine production. The data obtained were based on the records of national, regional and local organisations. The water footprint accounting was carried out according to the approach outlined in the water footprint manual provided by the water footprint network (Popa, 2009).

Grapes are the main ingredient in wine-making and therefore it was assumed that 1 litre of wine is made from 1.3 kg of grapes and 2 litres of water (Popa, 2009).. The outcome of the study indicated that by adding the green, blue and grey water a total water footprint for a glass of wine ranged between 165 litres of water per glass in 2006 (normal year) to 343 litres of water per glass in 2007 (dry year) (Popa, 2009).

2.3.11. WATER USE IN BEVERAGE INDUSTRY

The BIER study conducted in 2012 was their sixth annual water benchmarking study. The study evaluated the performance of more than 1 600 beverage manufacturing locations, which represented 17 different beverage companies (BIER, 2012c). Each of the 17 companies was requested to report on three years (2009–2011) of facility-specific data (see Figure 2.10). The total water used at all the facilities was calculated by focusing on the volume of water used for beverage production, packaging, cleaning/sanitation processes, cooling, heating, sanitation, landscaping and storm water. A total of 73% of the facilities reported an improvement on their water use ratio from 2009 to 2011. It was noted that facilities with higher production volumes than lesser production facilities showed a bigger saving in water use ratio. The improvement of water use efficiency for the beverage industry is related to saving approximately 35 billion litres of water in 2011 – enough water to fill London's 02 Arena more than 16 times (BIER, 2012c). Of the 725 carbonated soft drink bottling sites, 74% showed an improved water use ratio from 2009 to 2011.

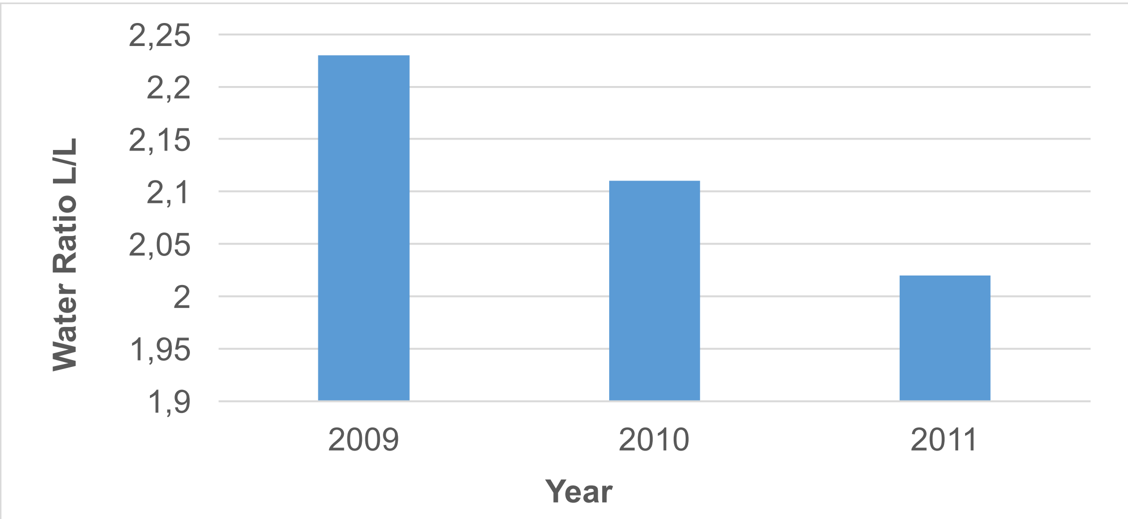


Figure 2.10: Water use ratio for the carbonated soft drink industry between 2009 and 2011 (BIER, 2012c)

Of the 131 bottling facilities, 75% showed an improvement in water use ratio from 2009 to 2011, as shown in Figure 2.11.

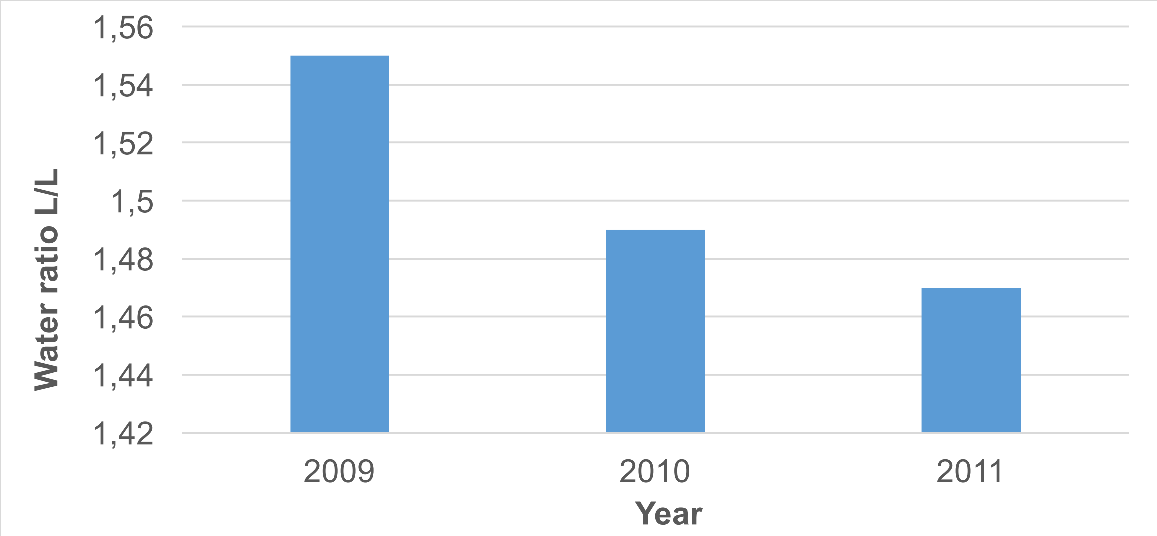


Figure 2.11: Improvement of water use for the carbonated soft drink industry between 2009 and 2011 (BIER, 2012c)

As shown in Figures 2.10 and 2.11, improvements can be seen from the first water footprint assessment in 2009 and those in 2010 and 2011. In 2011 the water footprint was set at 2.02 and after improvements and better water management, the water footprint dropped to 1.47 (l/l). The Brampton Coca-Cola plant in North America reduced its water use by 20% reaching a 1.62 l/l ratio (Wong, 2011).

An updated study was conducted in 2012 indicating a decrease of 4% of water use ratio for all types of beverage manufacturing organisations (BIER, 2013). The water use ratio decreased from 2.92 l/l to 2.69 l/l as shown in Figure 2.12.

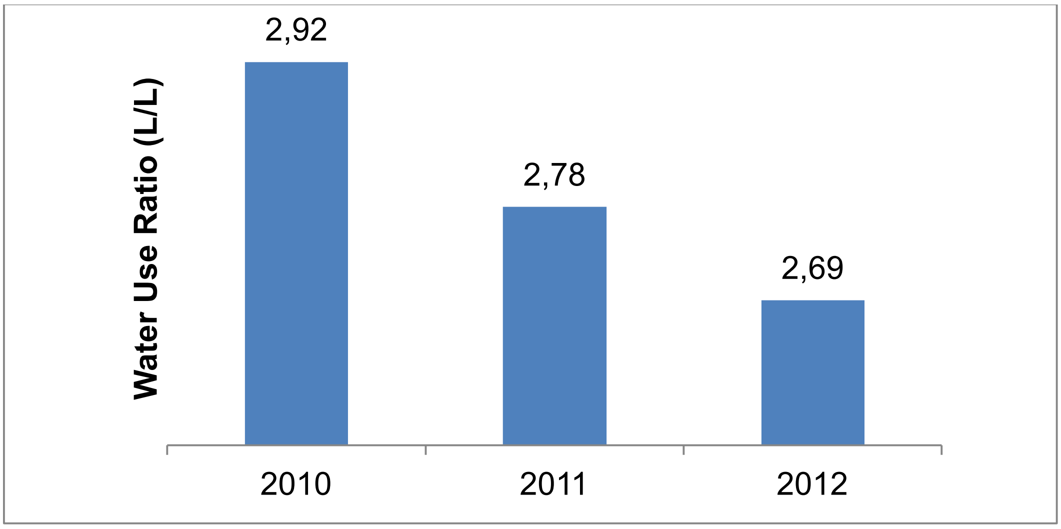


Figure 2.12 Water ratio study conducted from 2010 to 2012 (BIER, 2013)

The improvement in water efficiency over the above-mentioned study period corresponds to water use of approximately 65 billion litres in 2012, enough water to fill New York's Empire State Building 62 times (BIER, 2013). As previously mentioned, Figure 2.12 shows the combined results for all the beverage manufacturing companies that participated in the study conducted by BIER. If only the carbonated beverage facilities are considered, a decrease in 69% of water use ratio is noted as per Figure 2.13 (BIER, 2013).

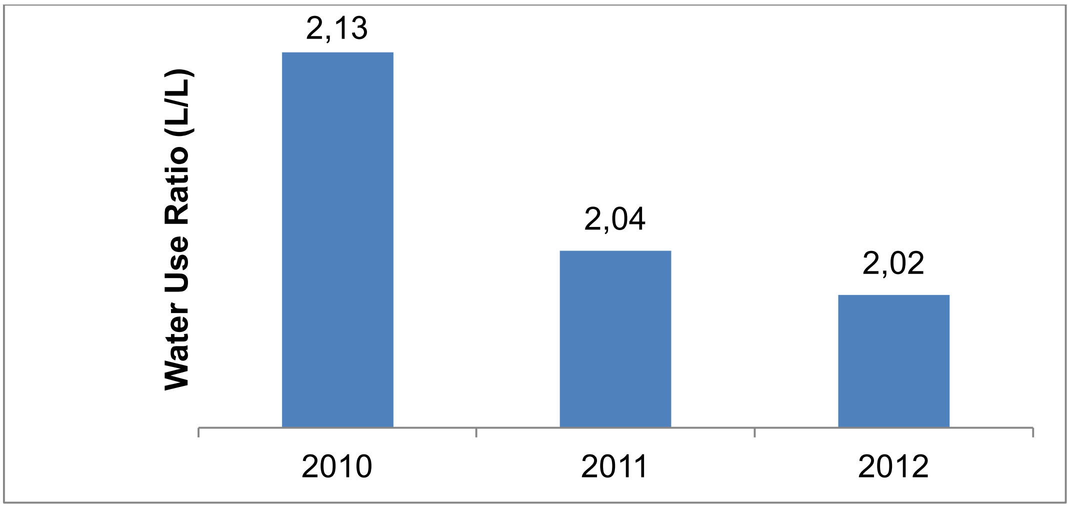


Figure 2.13 Water use ratio for carbonated beverage facilities (BIER, 2013)

The carbonated beverage companies showed a decrease from 2.13 l/l water use ratio to 2.02 l/l water use ratio.

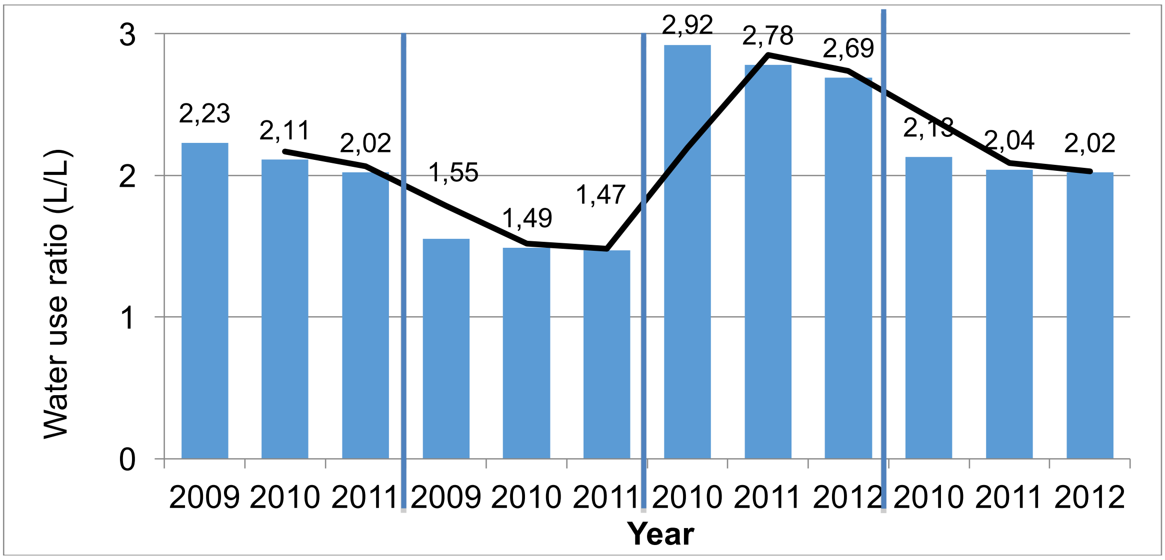


Figure 2.14: Total reduction found in the studies conducted by BIER (BIER 2012a; 2013)

2.4 BENCHMARKING

Many South African companies apply regulatory compliance as their primary environmental indicator. Beyond compliance, however, some companies apply sustainability metrics as their main environmental indicator. According to the White Paper, sustainability metrics provided a broader view of the environmental picture for a facility, one that fits comfortably within corporate summaries (RSA, 2011). While sustainability is commonly used to compare facilities within the same company, it is not always quantified as a single score. At present, many companies score the sustainability of their operations (RSA, 2011).

2.5 SUMMARY

In view of the need to reduce environmental impacts and to save future resources, climate change and the responsibilities of governments and organisations are important topics for discussion at present. Since the 1970s, government bodies have made considerable efforts internationally to set up and implement environmental policies at levels varying from the local to the global (Crabbe & Leroy, 2008). More recently, private businesses and non-governmental organisations have increasingly been engaging in environmental policies (Crabbe & Leroy, 2008). The question for companies is not *whether* to take action on climate change, but *when* (Hoffman, 2010). The importance of the Carbon Disclosure Project and the disclosure of organisations' emissions are highlighted. As per the 2014 Global Risk Report, water scarcity is third on the list and the failure to mitigate and adapt to climate change is fifth (WEF, 2014). It is not just water quantity that is a critical issue, but also the water quality. Pollution incidents have paralysed businesses in certain parts of China and elsewhere (WEF, 2014). Undeveloped countries are making limited progress on issues such as emission reduction, loss and damage compensation and adaptation. Greater progress is needed to create incentives within these countries (WEF, 2014).

In this chapter, carbon and water footprints were defined and explained (Appendix A). The different levels of reporting, namely Scope 1, Scope 2 and Scope 3 for carbon footprints were briefly discussed and the definitions of grey water, blue water and green water footprints were given. Current international and local carbon and water footprints were discussed and set footprint benchmarks for comparison later in this study.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGIES

3.1. INTRODUCTION

The purpose of research is to increase knowledge by conducting inquiry into the relevant topic on a systematic manner (Collins & Hussey, 2003). Collins and Hussey (2003) also classify research according to the following aspects:

- Purpose – identify what will be achieved by conducting the research
- Process – identify how data are collected and analysed based on various methods
- Logic – whether the research is generic or specific
- Outcome – whether the identified purpose was achieved and knowledge transferred to the reader

A research design, or the process, as stated above, is the manner in which data are collected and analysed to determine whether the purpose of the study or research was achieved. It also gives a conceptual structure in which the data will be analysed (Kothari, 2004). This chapter examines the methods for primary and secondary data collection in order to fulfil the research objectives, which are demonstrated in Figure 3.1.

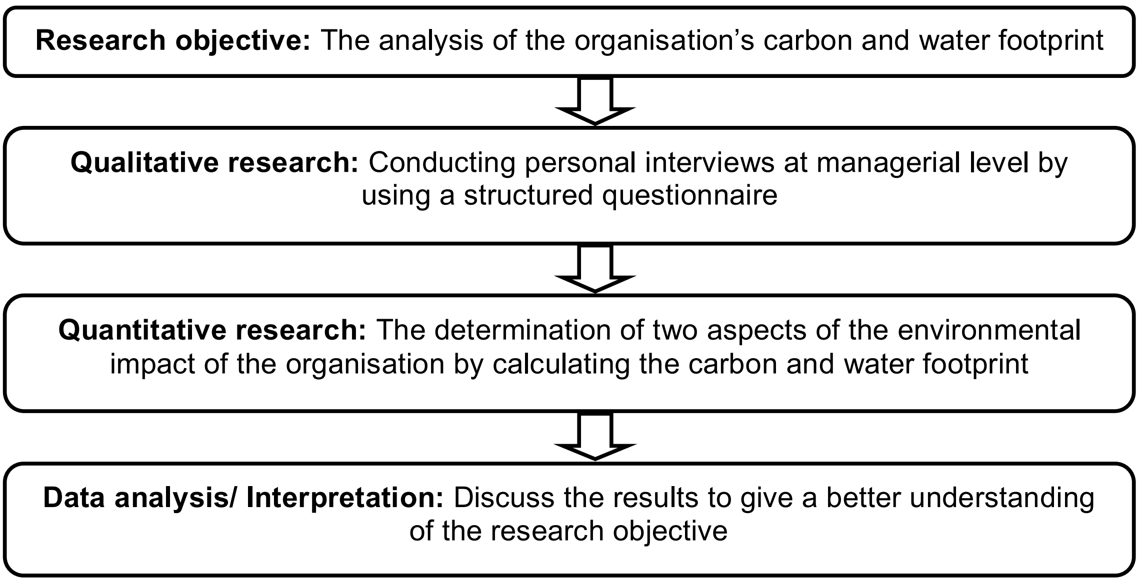


Figure 3.1: Research roadmap adapted from Creswell & Clark (2011)

3.2. RESEARCH DESIGN

The aim of this study was to determine the carbon and water footprint for a manufacturing company and as previously noted in Chapter One. This study was exploratory in nature and based on a quasi-experimental research design, which means that a mixed methods design was used. Experimental design is the section of the research where the effect of the tested variables is compared against other variables (Campbell & Stanley, 1963). There are many ways in which the researcher can incorporate an experimental design during the data collection by identifying when measurements were taken and by whom (Campbell & Stanley, 1963).

Experiments are important to understand because quasi-experimental designs, which are research designs similar to true experiments, can only be fully appreciated when compared to the experimental ideal (Donley, 2012). An evaluation is done after the research has been completed to ensure that the purpose of the research was successful or effective (Mouton, 2011).

A quasi-experimental design is an empirical design in which both numerical and textual data are used (Mouton, 2011). Mixed methods research designs entail the collection of data or numbers as well as the collection of words, through possible interviews (Creswell & Clark, 2011). In this study, Chapter 2 provides the rationale for the research. Chapter 3 explains the process used by the beverage manufacturing company at the time of the research and in Chapter 4 the quantitative results are discussed. The data for Chapter 5 were sourced from systems within the beverage manufacturing company. Quantitative researchers use qualitative data within their research based on the recognition of the importance of qualitative data. Qualitative researchers must be aware that only reporting qualitative participant views might make it difficult for some to understand the findings fully (Creswell & Clark, 2011). As a result this study makes use of both qualitative and quantitative data.

3.2.1. DATA COLLECTION APPROACH

According to Walliman (2011), data can be analysed or interpreted in various ways, depending on their nature. Some of the measurements that can be used are the following:

- ❖ Nominal measurement: This is a very basic measuring system in which figures or statistical techniques are used.
- ❖ Ordinal level: More variety of statistical analysis can be applied at this level and in this study.

As per PAS 2050:2011 (BSI, 2011), the types of data needed to carry out a carbon footprint calculation fall into two categories:

- ❖ Activity data: The data reflect the amount of emissions for the inputs and the outputs for any process or product. The production figures presented in this study are a reflection of the activity data. In this study the activity data were sourced from ISO 14001 and inventory management systems. The carbon footprint calculations data were based on CO_2 usage for the manufacturing of the carbonated beverages, and Liquid Propane Gas (LPG) usage for the forklifts, boiler emissions for both heavy fuel and natural gas boilers. All the data were based on Scope 1 emissions. The Scope 2 emissions were from purchased electricity, which is an indirect emission. The activity data for the water footprint were based on the total incoming water and how this water was distributed within the manufacturing company.

- ❖ Emission factors: The emission data were converted into GHG emissions as units of kg CO_2e. Depending on the type of emission, the conversion value to GHG emissions differed from each emission source and each emission year. The values for the carbon footprint were sourced from local emission data or alternatively from the Department of Environment, Food and Rural Affairs (Defra) international source. In certain cases the manufacturing company data were measured in a different specific measuring unit than the source data, and therefore the manufacturing company data were converted to the preferred unit of measure. The carbon footprint data present the emission values that were used and the water footprint data presents the consumption values to determine the current status of the beverage manufacturing company.

Data sources for the calculation of a water footprint are dependent on the type of water footprint to be calculated (Hoekstra *et al.,* 2011). The blue water footprint for an industrial process can be measured either directly or indirectly. It was very complex to identify the water consumption within each production process because only one incoming water meter was in place within the beverage manufacturing company. Thus all the water used within the production process of the manufacturing company were combined and was used to calculated the water footprint of 1 lt unit product produced.

Both qualitative and quantitative techniques were used for this research in analysing the data and acknowledging the information received through interviews.

3.2.2. SAMPLING TECHNIQUES

The identification of samples for research depends on the research question(s) that need to be answered (Leedy & Ormrod, 2010). Creswell and Clark (2011) recommend the following steps for sampling both qualitative and quantitative data:

- Collect the data by using the aspect register information of the beverage manufacturing company and collecting benchmarking data and information
- Use specific sampling techniques by interviewing key employees within the beverage manufacturing company
- Obtain permission to study the specific data by requesting ethical concession from the beverage manufacturing company
- Identify possible data errors in Chapter 5 and giving recommendations in Chapter 6

3.3. THE QUALITATIVE RESEARCH APPROACH

Qualitative data such as protocols, memorandums, interview transcripts, photographs or films do not speak for themselves; in qualitative research they are viewed as texts that have to be read (or interpreted) and related to available research results (Flick, Von Kardorff & Steinke, 2004). Qualitative approaches can be used to understand social and human activities by examining and reflecting perceptions about a specific subject matter (Collins & Hussey, 2003). Different descriptive sequences use one or several of these ways to collect primary data and customise them to cater for the needs of whoever wishes to use the data (Walliman, 2011). A qualitative methodology emphasises meaning and experience related to the phenomena, where a quantitative methodology attempts to measure variables or count occurrences of a phenomenon (Collins & Hussey, 2003).

It is necessary, during the sampling process related to interviews, to select the participants that have the most information regarding the specific topic under investigation (Leedy & Ormrod, 2010); in this research section the management of the beverage manufacturing company was the subject of investigation. Some well-known methods to collect primary data are interviewing, observing and experiments (Walliman, 2011). Key stakeholders were engaged and five participants were chosen for the structured interviews to collect qualitative data. The researcher needed to understand the managerial staff's general knowledge and commitment to the carbon and water footprint. A structured questionnaire and one-on-one interviews were scheduled with participants (Appendix B). The interviews were anonymous and participants had the right to stop the interview at any stage. All questions were based on the understanding of the carbon and water footprint concept and possible reduction plans (section 6.2.4 and 6.3.3). In this study, the qualitative data obtained from the manufacturing company during the interviews were referenced as "personal communication".

3.3.1 ANALYSIS AND INTERPRETATION OF QUALITATIVE DATA

Qualitative data are typically not presented using statistical procedures; the data are rather presented in such a way that the data speak for itself (Leedy & Ormrod, 2010). Qualitative researchers frequently include dialogues and statements to substantiate their findings (Leedy & Ormrod, 2010). Qualitative data focus and narrow down the purpose of the questions by including a central question and adding several sub-questions (Creswell & Clark, 2011). Qualitative data need to address how the research question was answered by the qualitative findings. Qualitative researchers may also bring in their personal experience and draw personal assessments of the meanings of the findings (Creswell & Clark, 2011).

Structured interviews involve schedules where all questions, fully formulated, are pre-given and asked in the same order, and ideally in the same manner, for every interview (Griffin, 2005). In this research, the outcomes of the one-on-one interviews at managerial level were analysed and interpreted in such a way that the researcher could determine the general knowledge about the research concept. It was believed that a direct link could possibly be made with the level of knowledge versus the outcome of the carbon and water footprint.

3.4. THE QUANTITATIVE RESEARCH APPROACH

The objective of the quantitative research stage is to determine the carbon and water footprint of the manufacturing organisation. The quantitative approach was followed in this research to ensure statistical tests were applied by collecting and analysing numerical data to reach the objective in determining a carbon and water footprint for the manufacturing company (Collins & Hussey, 2003). Students make use of secondary data that is produced by teams of expert researchers, with extensive resources way beyond the means of a single student (Walliman, 2011). Secondary data and primary data collected can be benchmarked against each other to identify possible areas of improvement and to put the data in a larger context (Walliman, 2011). The disadvantage is that one does not gain the experience and skills of having to generate one's own primary data from real-life situations (Walliman, 2011).

In this research, the data were used to make better sense of the beverage company's position regarding emissions and water usage, which would assist in the aspects from the organisation's ISO 14001 information in relation to international benchmarking companies (Leedy & Ormrod, 2010). The organisation's emission data, with relevant emission factors, were used to determine the carbon footprint. The data on the water usage and effluent water quantities were used to determine the water footprint of the organisation.

3.4.1 ANALYSIS AND INTERPRETATION OF QUANTITATIVE DATA

Electronic spreadsheets and graphing capabilities are important tools that are being used by various organisations that have large amounts of data that need to be captured (Leedy & Ormrod, 2010). Quantitative data assisted with the research question of this study by narrowing down the purpose through hypotheses that made predictions possible about the related research question (Creswell & Clark, 2011). Interpretation of quantitative data means comparing the results with the initial research question asked to determine how the question or hypotheses were answered in the study (Creswell & Clark, 2011). The interpretation of the data is discussed in Chapter 7 of this study in relation to the research question and objective set for this study. The carbon and water footprint result is benchmarked against those of past studies, which provide explanations for what the researcher found in relation to this study (Creswell & Clark, 2011).

The methodology approach taken for this study is illustrated in Figure 3.2. The first step for the organisation was to determine the boundaries for both the carbon and the water footprint. The decision was based on what was measured and what was managed. The carbon footprint boundaries were based on direct and indirect emissions over which the organisation had control; therefore Scope 3 was not part of the carbon footprint calculation. The data on the four years emissions for each emission source were obtained from the beverage manufacturing company data. Only monthly data were available for the calculations and not daily figures.

After determining the average emissions per year, the specific emission factor for each emitter was used to determine the footprint for each source per production year. The emission factor of each emitter was sourced from the Department of Environmental, Food and Rural Affairs (DEFRA) to calculate Scope 1 and Scope 2.

The water footprint boundaries did not include the green water footprint. The green water footprint is related to the re-use of rainwater, which was not part of the beverage company scope. The blue water footprint was calculated by determining the total water usage per production year against the total production volumes produced per production year. The grey water footprint was calculated by determining the amount of water lost in the system against the total production volumes per production year. The pollutant grey water footprint was calculated by determining the pollutant load in the water per production year. Similar to the carbon footprint only monthly figures were available and not daily figures.

Figure 3.2 illustrates the carbon and water footprint methodology approach used in this study.

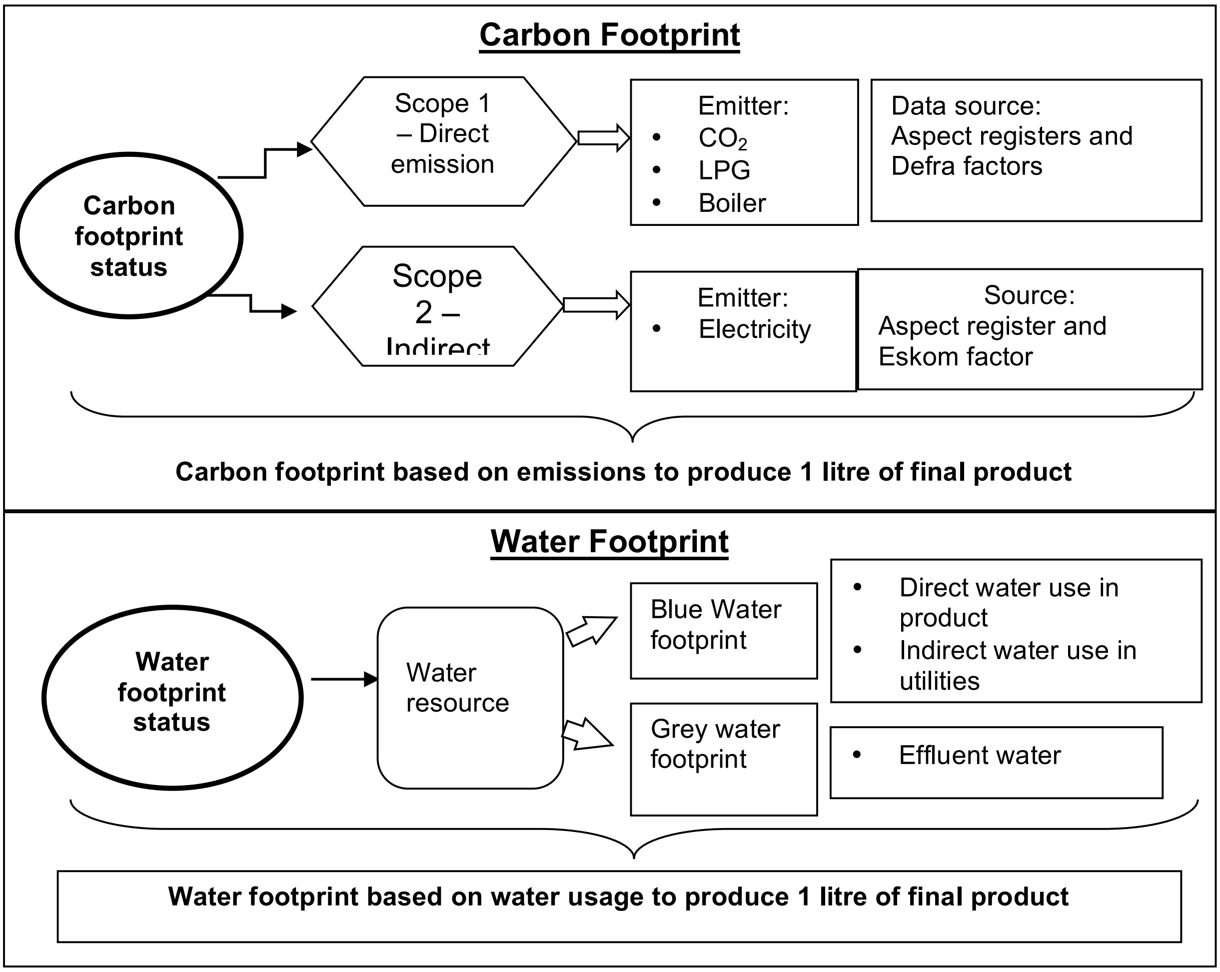


Figure 3.2 Carbon and water footprint methodology approach (Beverage manufacturing data)

The beverage manufacturing company's reasoning regarding both the carbon and the water footprint was to understand the current maturity of their resources and the managing of the resources. The company determined what sustainability aspects to include in reporting and to research in order to gain an understanding of their current status and reporting risk. The implication of the current status and what to disclose for both the carbon and the water footprint influences the future strategy and gives stakeholders a better insight of the current practices within the organisation (Schulte, 2014).

3.5. ETHICAL CONSIDERATIONS

Ethical considerations form an important part of research to ensure that the research was conducted according to a high ethical standard (University of Minnesota, 2013). "Ethics" is an umbrella term that can cover the particular code of ethics of a training body or organisation and the general approaches linked to the way in which one wants to socially treat someone coming into a counselling work environment, or as a research participant within a humanistic paradigm (Gardner & Coombs, 2010). This current research was reviewed and approved by the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences of the University of South Africa. The ethics clearance reference number is 2013/CAES/006. The outcome of the study will be shared with the beverage manufacturing company. Interviews were allowed with employees of the beverage manufacturing company but no reference to the company's registered name or names of the interview candidates were allowed.

Most ethical issues in research fall into one of four categories (Leedy & Ormrod, 2010):

- ❖ Protection from harm – The researcher must ensure that the interview participants of the research are not harmed in any way. This aspect was met in the current research.
- ❖ Informed consent – All interview participants must be informed regarding the nature of the research. In the current research participation was voluntary and each participant had the right to abort the interview at any time.
- ❖ Right to privacy – The information used from interviews must be presented in such a way that there is no invasion of the participants' privacy. In this research the participants could not be identified through their responses to the questions posed in the interview.
- ❖ Honesty with participants – The researcher must be honest in dealing with the participants and their responses. No information whatsoever was fabricated to support a particular conclusion in this research.

3.5.1. ACQUIRING PERMISSION TO DO RESEARCH AND INFORMED CONSENT

Permission was obtained from the technical director at the manufacturer's head office to use the manufacturing site's secondary data for this study. The researcher explained to each participant the reason for the research, as well as why and how the research would be conducted. Each participant acknowledged his/her agreement by signing a consent form. The interview information with each participant and their consent was captures in an interview questionnaire (Appendix B).

3.6. CREDIBILITY OF RESEARCH FINDINGS

Every research project has a certain level of error in measurement which is defined by reliability of information and the validity of the information (Leedy & Ormrod, 2010). Responsibility for all errors, omissions and opinions rests with the researcher, and findings, interpretations and conclusions expressed are entirely those of the researcher and not the views of the interviewees – in the case of this current study, the management team interviewed. Carbon accounting in this study entailed analysing and presenting information on greenhouse gas emissions of the products produced by the organisation under investigation in an attempt to identify major sources of emissions to the beverage company (Brenton *et al.,* 2010). According to Brenton *et al.* (2010), within the food sector three types of action can be taken regarding carbon accounting:

- Voluntary response by companies to the challenge of climate change, which may bring commercial advantage through enhanced marketing and public relations
- Action by governments to encourage companies to reduce their emissions
- Action by retailers to stock only products that achieved a certain "standard" in terms of their carbon footprint

3.6.1. RELIABILITY

Reliability is achieved by ensuring that the entity being measured does not change during the measurement to ensure that the result obtained during the measuring process is reliable (Leedy & Ormrod, 2010). Creswell and Clark (2011) define quantitative reliability as information from the past, used to assess the reliability of the instrument test and retest results that needed to be addressed during the research (Creswell & Clark, 2011).

3.6.2. VALIDITY

According to Campbell and Stanley (1963), there are eight different classes of variables when internal data are validated, namely past data, maturation, testing, instrumentation, statistical analysis, biases and selection-maturation interaction.

Qualitative research focuses on the credibility of the researcher and the participants to ensure that information is accurate and can be trusted (Lincoln & Guba, 1985). One method to validate qualitative research is to request the participants to verify that the findings are accurate according to their reflection and their experiences (Creswell & Clark, 2011).

In the current study the quantitative data, the emission data and emission factors were analysed first before the qualitative data arising from the personal interviews. This method of analysing is used to link the knowledge of management with the organisation's emission data; therefore, the validation of the data was done through the second set of data, which would increase the validity of the results.

A third party was used to verify the emission factors for the carbon footprint calculation and to identify general calculation errors in both the carbon and the water footprint analysis.

3.7. ANALYSIS OF DATA

Based on the research design, the data limitations such as measurement errors (operationalising and measuring outcome) can be expected (Mouton, 2011). Research looks at data directly by way of the hypotheses, and guided by the problem, the data are collected and organised (Leedy & Ormrod, 2010). Statistical analysis is done to determine the significant difference between production years and production months. Since there was no access to daily figures, the statistical analysis in this study was not considered for daily figures but was rather based on monthly figures. The following types of statistical analysis were conducted:

- One-Way ANOVA: The analysis of variance was used to determine whether any differences could be identified between two or more population means and to understand whether the population means differed (Keller, 2009). The population information in this study was the production and emission data that was obtained from the aspect register.
- Two-way ANOVA: The effect on the response variable of two or more factors was examined. Analysis of variance was done to determine whether the levels of each factor differed (Keller, 2009)
- Tukey comparison method: This test is a more powerful test to determine a critical number determining if two corresponding population means differ (Keller, 2009).

Figure 3.3 illustrates the water footprint calculation for the beverage company. The water footprint was based on the product water footprint and the water was received from one source but used for various processes within the facility. All the water used was part of the calculation for 1 litre of product produced.

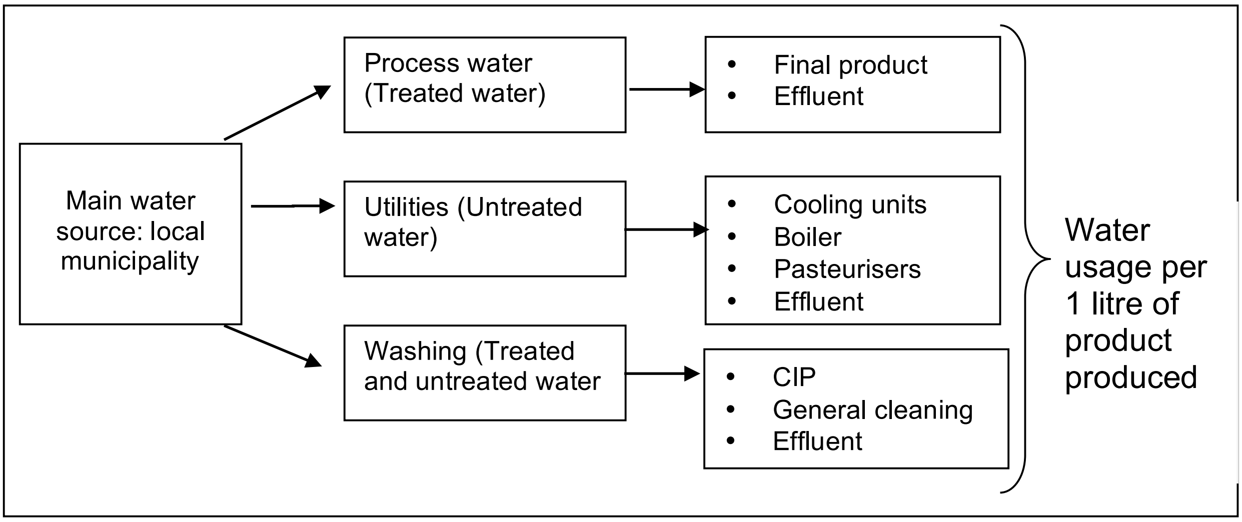


Figure 3.3: Water footprint for the beverage manufacturing company (Beverage manufacturing company data)

3.8. SUMMARY

Many researchers make one common error, namely to fail to exploit the data fully and to limit discussions of results only to the problem that has been identified (Leedy & Ormrod, 2010). This chapter detailed the method of data collection where qualitative data played a secondary role as greater emphasis was placed on the quantitative data. In Chapter 5 the analysis, results of the data. In Chapter 6 the recommendations for reduction are discussed. Chapter 7 presents the conclusion and the impact of the carbon and water footprint of the manufacturing organisation.

CHAPTER FOUR: MANUFACTURING PROCESS

4.1 INTRODUCTION

In the current study, research was conducted in a soft drink manufacturing facility that has been in operation since 1996. The corporate office has established various environmental sustainability programmes; hence, the opportunity to conduct this particular footprint study for the specific manufacturing site. It is believed that this study will set a benchmark and provide the corporate office with a tool to promote awareness of commitment to sustainability. Currently, systems for sustainability monitoring are in place as in accordance to ISO 14001 aspect register.

A typical beverage-processing map (see Figure 4.1) can be defined as per BIER (2010).

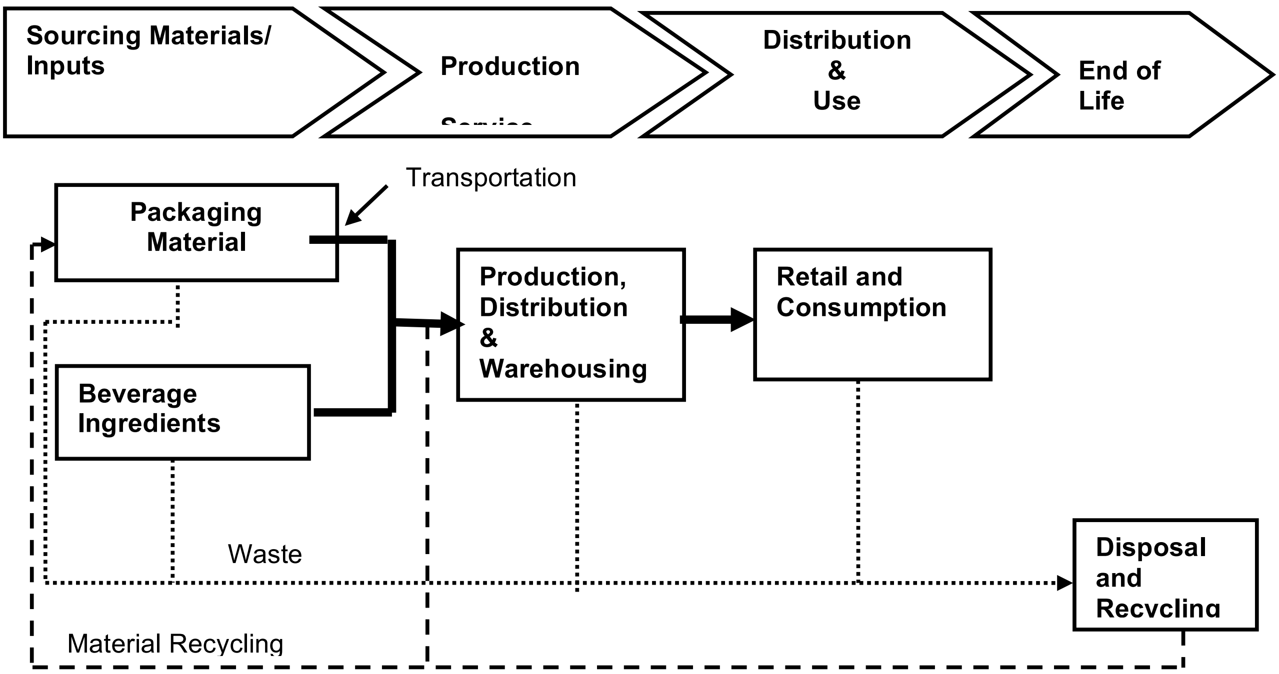


Figure 4.1: A typical beverage process map (BIER, 2010)

4.2 PROCESS OUTLINE

The first process step is the function of the inbound department, where the raw and packaging materials are received from approved suppliers. All raw materials must meet all Food Chemical Codex specifications and be approved for use by the Food and Drug Administration (Morrow & Quinn, 2007). After the acceptance process from the laboratory, the raw production and packaging materials are issued to the blending and production department respectively (see Figure 4.2).

The raw materials consist of acids, preservatives, flavourant and colourants. The organoleptic profile (taste and odour), solubility, microbial stability and temperature stability are important quality factors. The raw materials are pre-weighed as per the product recipe quantities and issued as batches to the blending department. Packaging materials can be classified as primary and secondary packaging. Primary packaging is in direct contact with product (cans and bottles) and secondary packaging (outer shrink film) is on the outside of the primary packaging (Reddy, 2010). The current metal container market share is estimated to be 410 billion units per annum; of this, drinks metal cans account for 320 billion (Coles & Kirwan, 2011). PET is the fastest growing plastic used for food packaging applications because of its use in all sizes of carbonated soft drinks and mineral water bottles (Coles & Kirwan, 2011). The packaging materials are issued in bulk quantities to the production department.

The blending department handles two main processes, namely the blending of simple syrup (the key ingredient for the sugar-containing beverages) and the blending of all the different raw materials for the final beverages. Simple syrup is the solution of water mixed with granular sugar. The manufacturing plant receives granular sugar from approved suppliers. Granular sugar is a nutritive sweetener from either cane or sugar beets. A certain amount of granular sugar (sugar cane) is blended with heated treated water (to ensure the sugar dissolves easily into simple syrup) and has a sugar content of about 60^{o}Brix. The Brix scale indicates the weight of sugar per volume of solution at a given temperature (Dictionary.com, n.d.). The simple syrup is stored at ambient temperature in bulk storage tanks. The sugar is transferred to the blending tanks via specific micron-sized filters to remove any foreign matter that could otherwise have been introduced in the simple syrup. Figure 4.2 illustrates the process flow of the manufacturing company.

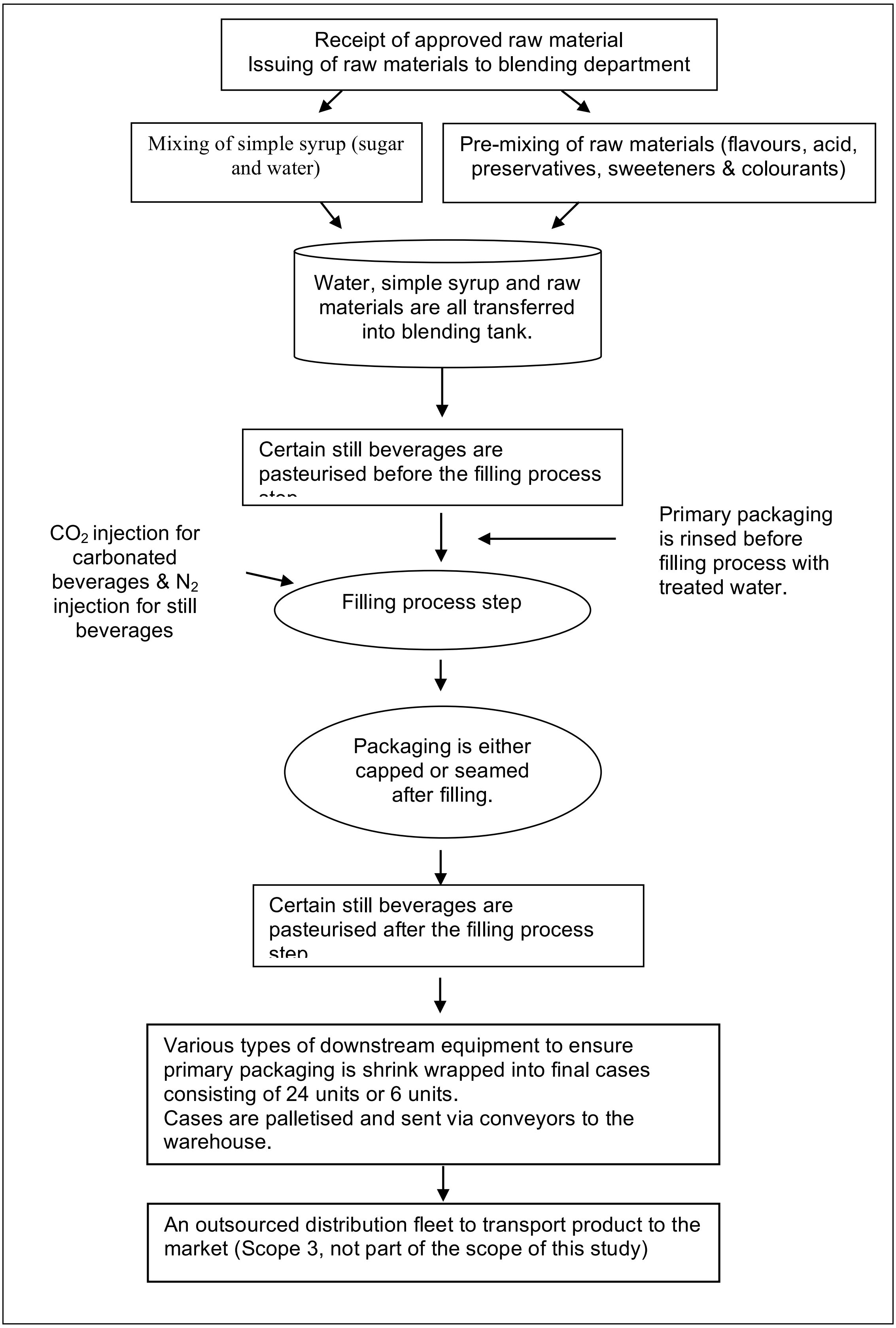


Figure 4.2: Process flow of the manufacturing company (Beverage manufacturing data)

All the beverages are mixed as a concentrated beverage and not as a ready–to-drink mixture. The beverages are blended in two phases, which are automated using the Supervisory Control and Data Acquisition (SCADA) software program. The first phase entails the automated transfer of the correct volume of simple syrup and treated water to the blending tanks via flow meters. The second phase involves the manual decanting of the raw materials into a pre-mix tank. After the raw materials have been dissolved and mixed, the mixture is transferred to the main blending tank, which already contains the water and simple syrup mixture. All the mixing tanks require agitators to mix the viscous syrup without affecting the flavour by shearing or destroying the delicate flavour blends. Once all the materials have become a homogenised mixture, a sample is drawn from the tank and analysed before the final release is issued by the laboratory.

Thereafter, the concentrated beverage is transferred to a production sequence A, B, C, D or E. On production sequences A, D and E, carbonated beverages are produced, production sequence B and C can produce either carbonated beverages or still beverages. On production sequence B the still beverage is pasteurised via a tunnel pasteuriser at 75^{o}C for minimum of 7 minutes. On production sequence C the still beverage is pasteurised via a tube pasteurisation unit before the filling process. Pasteurisation temperatures are between 91^{o}C and 100^{o}C. Sterilisation kills microorganisms and prolongs the shelf life of products (Ansari & Datta, 2013). Pasteurisers can use up large amounts of water which is often discharged directly to the effluent drain (Judd & Jefferson, 2003).

Empty beverage containers (metal cans, glass and PET bottles) are pre-rinsed with treated water, by means of an on-sequence rinser before the filling process is begun. The on-sequence rinser automatically inverts the packaging material and water is sprayed via nozzles into the packaging to create a rinse effect. The rinsed water is transferred back into the water treatment system for re-use and therefore a limited amount of water is wasted. Production sequence E consists of an in-line blow moulder, to blow PET bottles.

The filling process starts with the mixing of the concentrated beverage with treated water, to the correct beverage proportions and Brix scale, and then the finished beverage mixture is carbonated. Some beverages are produced as a still product, with the injection of nitrogen. The carbon dioxide (CO_2) and nitrogen (N_2) used in the production process is food grade. The CO_2 provides soft drinks with a pungent taste, acidic bite, and sparkling fizz. CO_2 is a colourless gas of slightly pungent odour and is the only gas suitable for producing the "sparkle" in soft drinks (Glevitzky, Brusturean, Perju, Laslau & Matyas, 2005). The CO_2 and N_2 also act as preservatives against microbiological contamination. The still beverages produced on production sequence C undergo pasteurisation before the containers are filled. The rinsed containers are filled with the beverage, thereafter the container is sealed by applying a plastic closure, and metal cans are sealed by a seaming process. The still beverages produced on production sequence B undergo pasteurisation before the cans are transferred to the down-stream equipment.

Each newly filled container is transferred via a conveyor system to the down-stream packaging equipment, where the product is cased into either six or 24 pack shrink-wrapped cases. The cases are palletised, and the pallets are sent to the warehouse for storage awaiting distribution.

The finished products are transferred to the outbound warehouse via a conveying system. The entire distribution system is outsourced to transportation companies and the manufacturing site does not have its own fleet of distribution vehicles.

The water is the largest single ingredient used in soft drinks and it must have a high purity level (Morrow & Quinn, 2007). The water used at the manufacturing process is supplied by the local municipality and the manufacturing facility has an on-site water treatment plant to remove contaminants that may affect the taste, odour, and appearance of the final product. Throughout the treatment process various types of chemicals are used to disinfect and soften the water. The main treatment process is the ion exchange and reverse osmosis process. Ion exchange removes inorganic materials from water. Reverse osmosis removes most water contaminants, such as microbiological contaminants, dissolved ions and organic material (Morrow & Quinn, 2007). Water consumption and pollution are associated with activities such as cleaning, cooling and processing. The water supply system within the manufacturing organisation is illustrated in Figure 4.3.

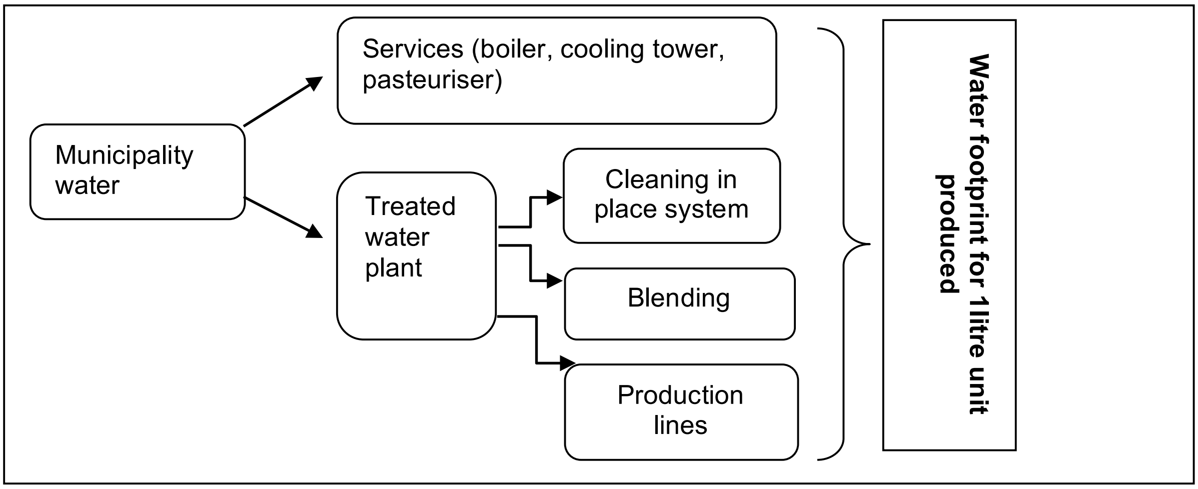


Figure 4.3: Water supplies for the beverage manufacturing company (Beverage manufacturing data)

The waste generated at this manufacturing site is both organic and non-organic. The organic pollution in the waste water is mainly sourced from the production process, for example, the in-sequence automated cleaning of the mixing tanks and production equipment, damage and/or breakage of finished products on the production sequence, sequence lubrication, and general manual cleaning processes. All packaging waste (cans, PET, glass, shrink film and cartons) is recycled. The use of recycled packaging material is more beneficial in the reduction of CO_2 emissions than the reduction of manufacturing energy and transportation of the packaging container (Coles & Kirwan, 2011). Every 1 000 tonnes of recycled glass used to make new glass save 345 000 kWh of energy, 314 000 tonnes of CO_2 and 1 200 tonnes of raw material (Elliot, 2008). Across Europe, 43% of all used PET bottles were collected for recycling in 2007 with an average proportion incinerated energy recovery of 30% (Coles & Quinn, 2011).

The natural gas boiler generates steam for beverages that need to undergo pasteurisation and the heating of the chemicals used in the cleaning in place (CIP) process. The still beverages require pasteurisation and the emissions on the pasteurisation sequences are higher but will not necessarily influence the total carbon footprint calculation because the current emissions are allocated to the entire manufacturing facility based on all the products produced and are not line specific. The CIP process is the cleaning of all production sequences and blending tanks. The SCADA system also controls the CIP process. A CIP matrix is in place to ensure the correct cleaning process is followed between specific products and flavours. There are two different types of CIP processes:

- Three-step process: Rinse with water, either an acid or a caustic chemical wash and lastly flush with water.
- Five step process: Rinse with water, acid chemical wash, flush with water, then caustic chemical wash and lastly flush with water.

The manufacturing process has been described above, and the process related to carbon and water footprint is illustrated in Figure 4.4.

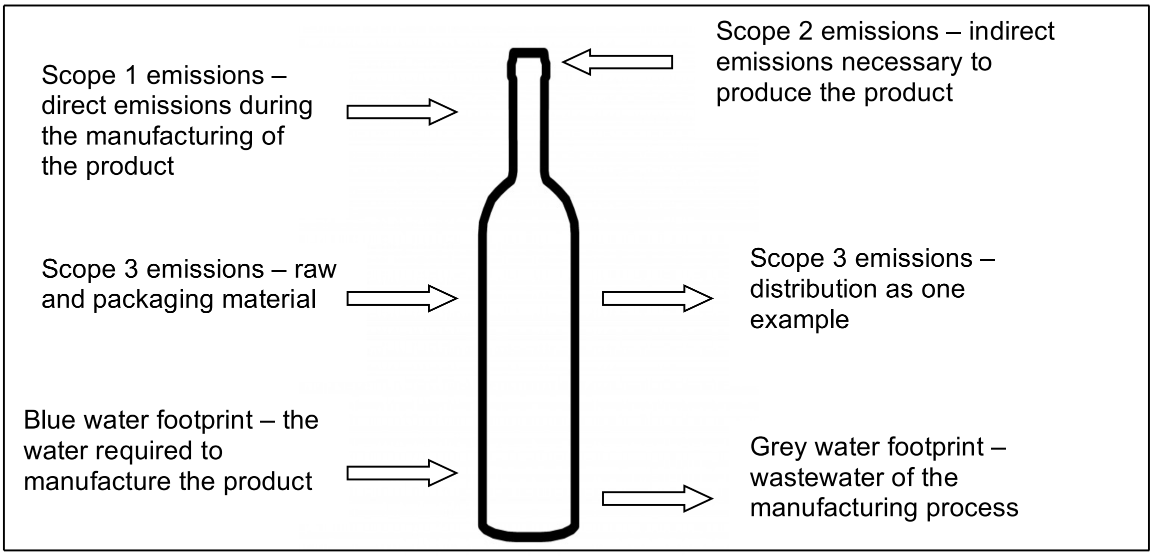


Figure 4.4: Carbon and water footprint in the beverage manufacturing process (compiled by researcher, 2015)

Scope 3 emissions are not part of the study but will be discussed in Chapter 6 as they are related to recommendations to the beverage company. The carbon and water footprint is calculated per 1 litre unit produced and is not related to the specific production sequence on which the beverage was produced, but rather as 1 litre unit produced within the beverage manufacturing facility.

4.3 SUMMARY

The overall process of the manufacturing company that was researched does not differ much from any other beverage manufacturing process. Some of the in-house production sequences are less automated, have lower production efficiency, and produce more waste than the newly installed and more efficient production sequences. The manufacturing company has an emission tracking system in place, based on the ISO 14001 certification requirements. The primary data for both the carbon and water footprint calculations were available from 2010 up until 2013.

CHAPTER FIVE: ANALYSIS AND RESULTS

5. PRODUCTION VOLUMES

5.1 INTRODUCTION TO PRODUCTION VOLUMES

There are five production sequences in the manufacturing company facility. Production sequence A produces carbonated soft drink (CSD) beverages, production sequence B produces CSD and still beverages, production sequence C produces CSD and still beverages, production sequence D produces carbonated beverages and production sequence E produces CSD beverages. In explaining the production volumes, the total beverage production volumes, then the CSD volumes and lastly the still beverage volumes are discussed since CSD volumes are much higher than still beverage volumes.

5.2 TOTAL BEVERAGE PRODUCTION VOLUMES

The higher production seasons in the South African beverage market are mostly the summer months from September to April and the low seasons are mostly the winter months between May and August. This distinction between summer and winter months is an in-house production planning method for the beverage manufacturing company. On some occasions, the production volumes differ from what is indicated above, but there are specific reasons for the different trends.

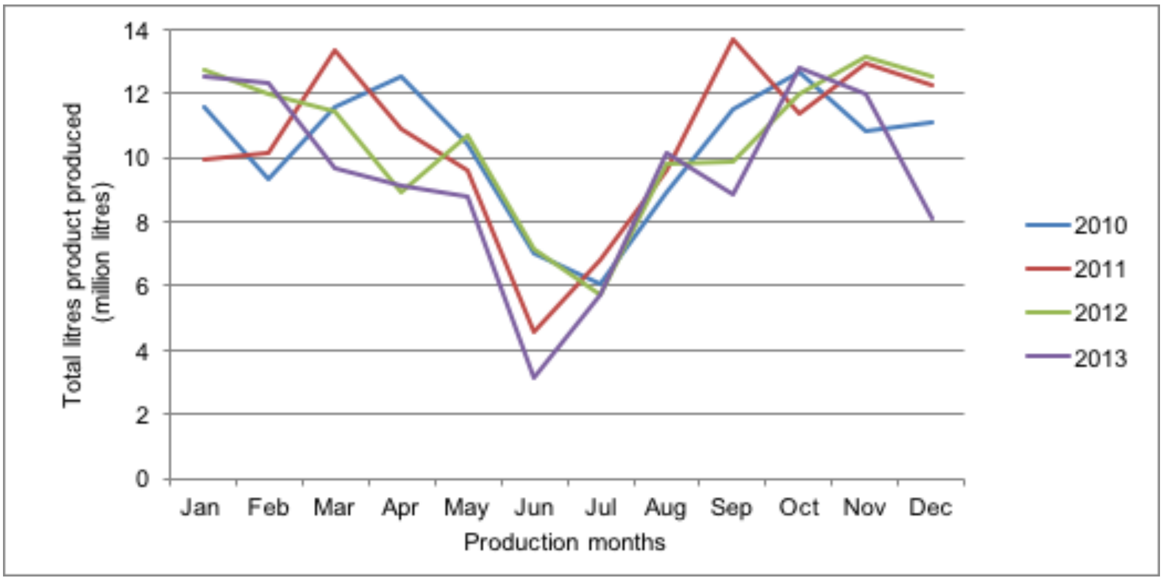


Figure 5.1: Total litres beverage production for 2010–2013. (Beverage manufacturing company data)

Figure 5.1 shows that the manufacturing company production volumes indicate a spike round March and April, the period that includes the Easter weekends. The manufacturing facility needs to build stock before the Easter seasons for each specific production year and fill the market after the Easter seasons. A two-way ANOVA was done to determine if any significant difference exists between the total production volumes for all four years (2010–2013) in terms of production months April till August. The two-way ANOVA indicated that there is a significant difference between the months with a p-value of 0.00056. The Tukey's Honest Significant Difference (HSD) test was applied in an attempt to understand which months are significantly different from each other (Figure 5.2; Appendix D). The data indicated that for certain months no significant differences were identified but for the following months a 5% significantly difference level was identified between production months:

- April and June
- April and July
- May and June
- May and July
- June and August

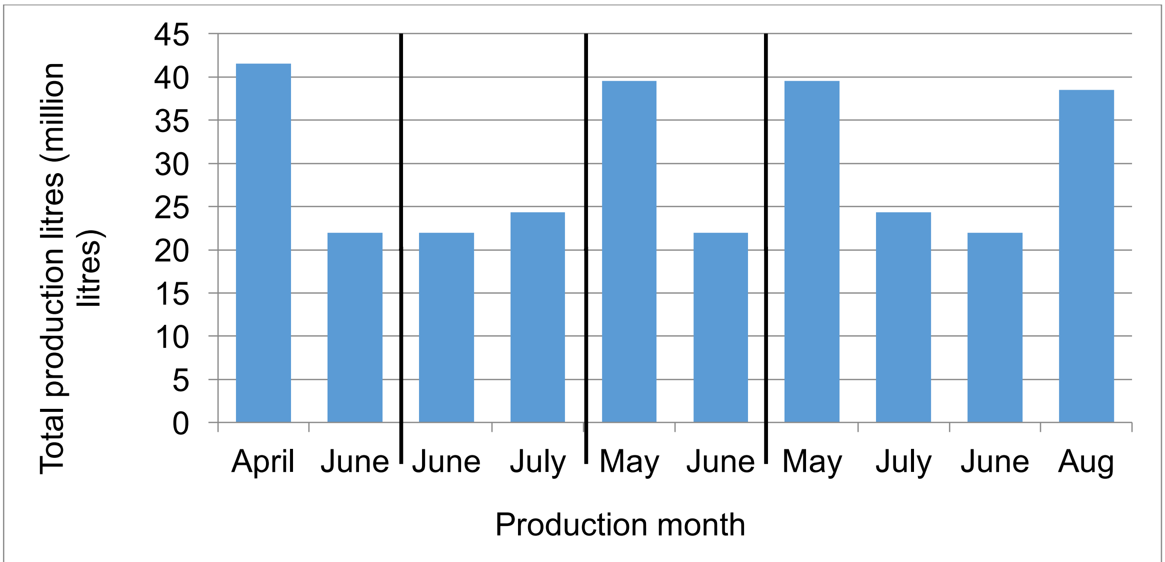


Figure 5.2: Statistical data between Easter and winter months presented in a bar chart (Beverage manufacturing company data)

This data can be used to give an indication to the beverage manufacturing facility that in the winter months (May to August) lower production volumes can be anticipated. April is a higher production month because of the significant difference noted between April and the winter months; this has a direct impact on production planning. It might also be that a lower carbon and water footprint can be expected for the winter months.

Statistical analysis was done to determine whether there is a significant difference between the winter months of each production year. The analysis indicated a p-value of 0.000048225, indicating a significant difference between all the winter months for each production year. The Tukey's HSD test indicates there is a significant difference between the following months of each production year (Figure 5.3; Appendix E):

- May and June
- May and July
- June and August
- July and August

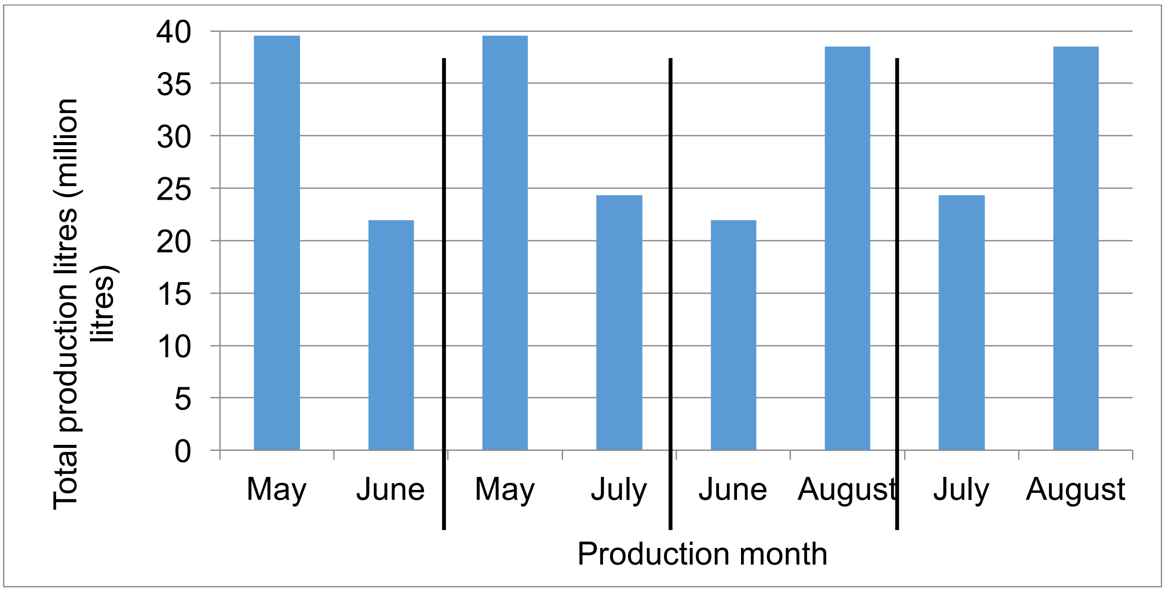


Figure 5.3: Significant differences between winter production months of all four years is illustrated by aid of a bar chart (Beverage manufacturing company data)

Figure 5.3 data indicates that for each production year the production volumes in June and July do not differ significantly from each other but there is a significant difference between June and July and the other winter production months. This is an indication that production months June and July, for each year, are most stable for all the production months and the lowest for all the winter production months. This information can be used to give the beverage company and indication for production planning during the winter seasons. The company can plan ahead that June and July will be lower production months and they can focus on preventative maintenance, reduce stock levels of packaging and raw materials and request employees to take their annual leave during the winter months. The total litres of beverage production per month and year for the period 2010–2013 are reflected in Figure 5.4.

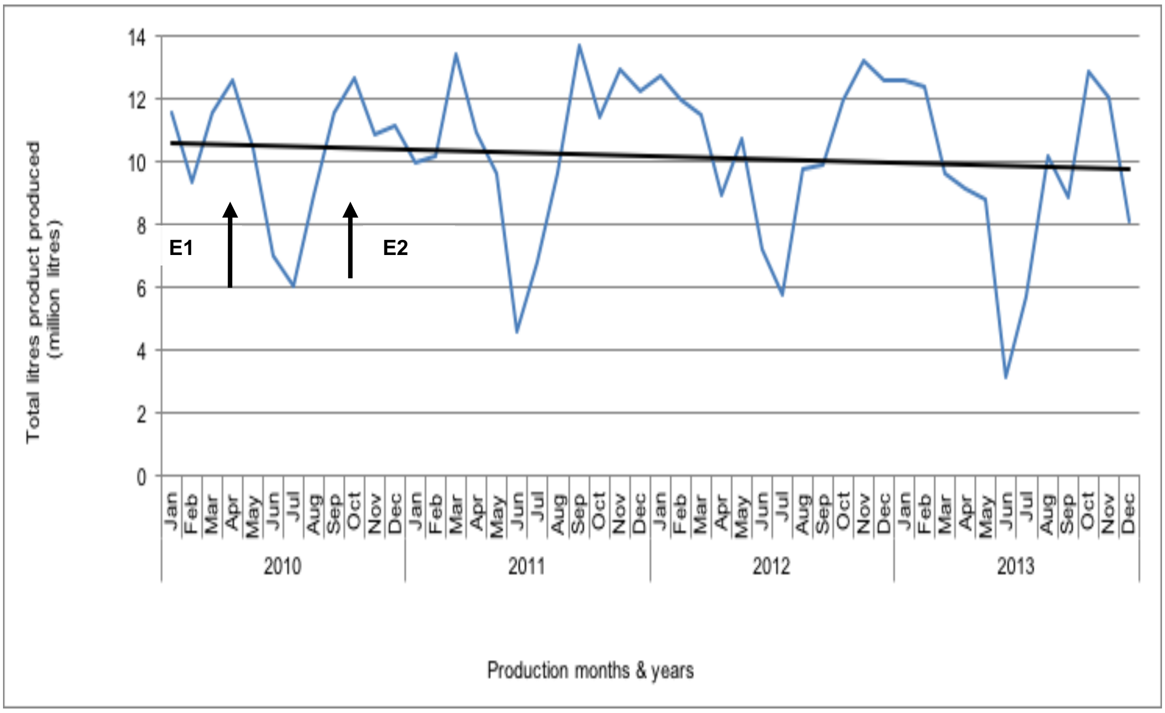


Figure 5.4: Total litres beverage production per month and year (Beverage manufacturing company data)

A gradual downward trend is noted (see Figure 5.4) for the total litres product from production year 2010–2013; it is possibly based on sales and consumer demand. The production facility amends the production plan as per meetings held with the sales team to understand the customer demand. April (Figure 5.4; E1) and September 2010 (Figure 5.4; E2) were the highest production months for production year 2010. The reason for the higher production is that the manufacturing company anticipated an industrial strike from June until August 2010 but the strike only occurred in October 2010. The high production in April was to build stock for the anticipated industrial strike from June until August in 2010. Since the strike only realised in October 2010, September was higher to build stock for the strike months and to ensure stock was available for the market. The lower winter months for each of the other production years are discussed later in the dissertation. Table 5.1 illustrates the total production figures in litres for all four production years.

Table 5.1: Total production figures in litres for production year 2010–2013 (Beverage manufacturing company data)

Production month and year	**2010**	**2011**	**2012**	**2013**
Jan	11 561 600	9 985 258	12 739 791	12 556 510
Feb	9 322 820	10 189 095	11 994 990	12 348 805
Mar	11 563 250	13 377 550	11 485 250	9 645 891
Apr	12 555 200	10 912 625	8 932 101	9 147 474
May	10 417 890	9 644 128	10 713 938	8 780 487
Jun	7 021 368	4 577 480	7 183 482	3 149 293
Jul	6 054 602	6 819 010	5 747 219	5 726 026
Aug	8 935 642	9 616 108	9 790 322	10 161 832
Sep	11 545 520	13 683 548	9 867 407	8 838 041
Oct	12 661 096	11 397 628	11 964 404	12 828 593
Nov	10 847 559	12 921 086	13 174 006	12 022 929
Dec	11 133 618	12 237 034	12 554 723	8 102 985
Total litres produced	123 620 169	125 360 554	126 147 637	113 308 869

Production volumes increase from September each year and a reduction occurs in January, which is a reflection on the increase summer months within the beverage industry (Table 5.1). This information provides a guideline to the beverage company that an increase of raw and packaging material will be required for the higher production months. During these higher production months the manufacturing company needs to ensure that the loss of product, water, packaging and resources is managed to a minimal. This can possibly lead to higher carbon and water footprints during higher production months. Statistical analysis indicated that there is no significant difference between summer production months (Appendix F), which indicates that the manufacturing company can have similar plans for all the summer months.

Figure 5.5 indicates the analysis per production sequence per month of each production year.

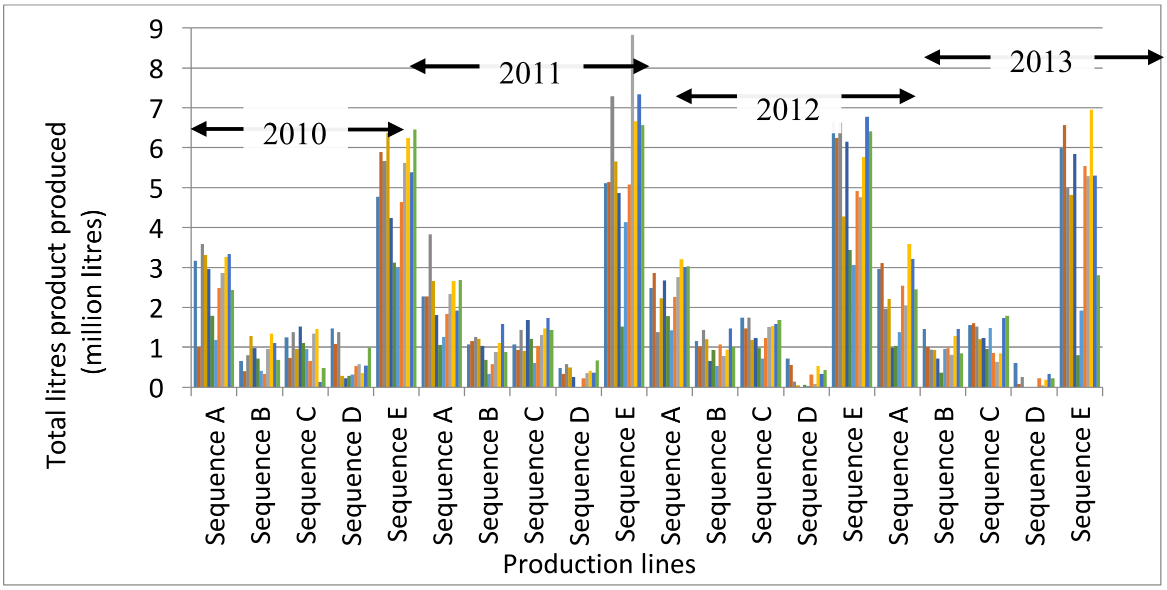


Figure 5.5: Total production litres produced per production sequence for each production year (Beverage manufacturing company data)

There are five production sequences in the manufacturing company facility. Sequence A produces units of more than 2 litres, sequence B produces units less than 500 ml, sequence C produces units less than 2 litres, sequence D produces units less than 500 ml and sequences E produce units of more than 2 litres. Sequence E produces most of the CSD volumes due to the high production efficiency of this production sequence. The information presented in Figure 5.5 illustrates that sequence D produces the lowest volumes and a decrease is noted within each production year. It is also noted that sequence E is the sequence with the highest production volumes within the facility. Figure 5.6 indicates all the production sequences over the four production years.

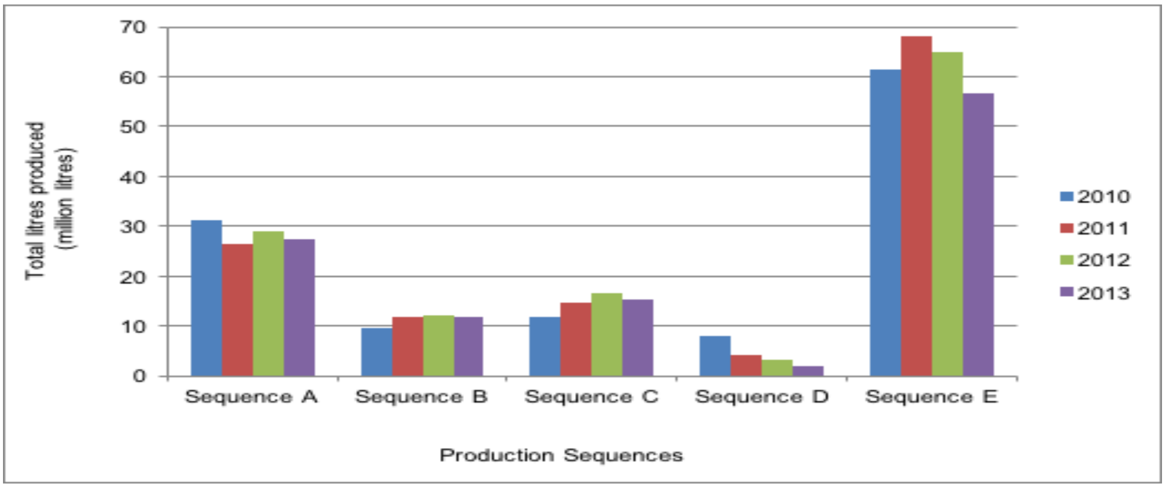


Figure 5.6: Total litres produced per production sequences A to E for each production year (Beverage manufacturing company data)

The production volumes on sequence A were the highest in production year 2010 and the lowest in production year 2011.

Sequence B production volumes stayed more consistent than the other production sequences and an actual increase in production is noted on sequence B for the first three years and a slight reduction in production year 2013.

The increase in carbonated volumes of sequence C since 2011 was due to the introduction of numerous promotions on sequence C and then the addition of the still beverages. The lower levels in production year 2013 were due to the relocation of the still beverage production to the other production facility.

Sequence D carbonated production volumes reduced each year, which was based on a business decision by the beverage company head office.

The production volumes on sequence E are much higher than any of the other production sequences, which is possibly due to better line controls and production efficiency of sequence E.

It is noted that production year 2013 is the lowest production year for all four production years and there is a lower production in all the sequences in 2013 compared to 2012.

Figures 5.7 to Figure 5.11 illustrate all the production sequence volumes for each production year over the four years.

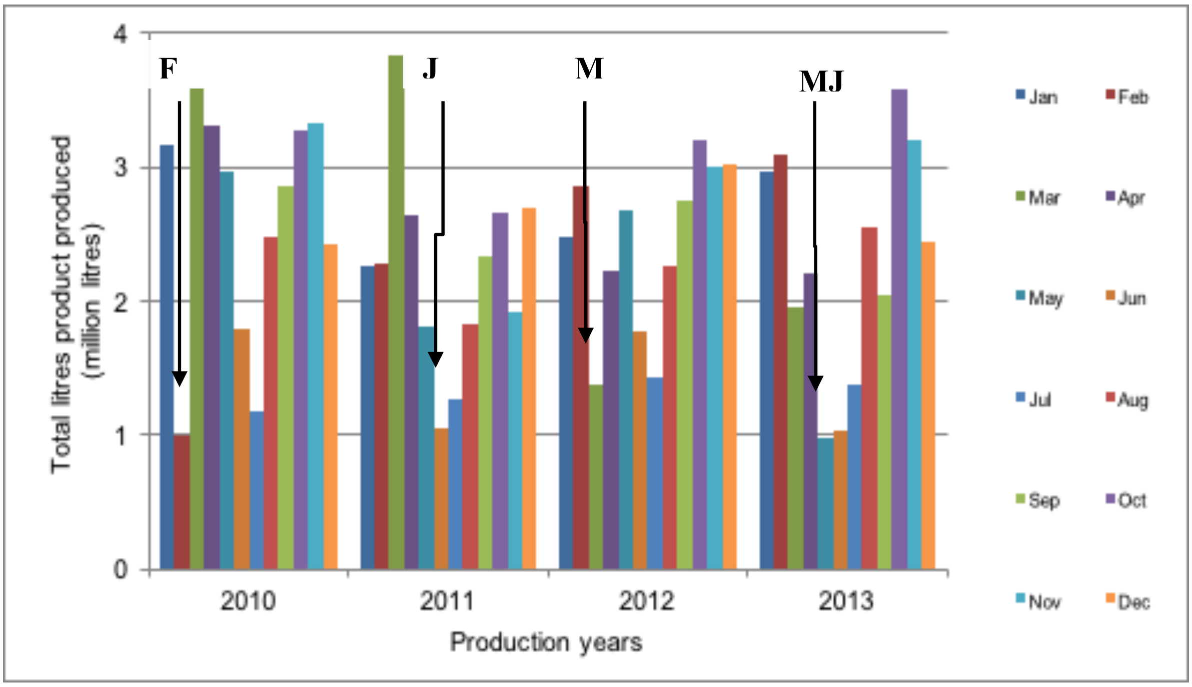


Figure 5.7: Total litres produced on production sequence A for all the production years (Beverage manufacturing company data)

One of the outliers on production sequence A is the February 2010 (Figure 5.7; F) production volumes. This is another indication of seasonal demand. January 2010 had higher production volumes due to high sales in December 2009 (data not shown); therefore the February 2010 production was much lower than January 2010 because the January 2010 production was aimed at filling the market based on higher sales volumes in December 2009. The reduction in volumes as in June 2011 (Figure 5.7; J) was due to the replacement of a labeller on production sequence A and possibly also due to the fact that maintenance is mostly scheduled for the winter months. The lower volumes in March 2012 (Figure 5.7; M), were due to the higher volumes in February 2012. An increase in production volumes is noted in April 2012 based on the Easter weekend. Similarly, the higher volumes in February 2013 were noted for the Easter weekend in March 2013. The lower production volumes from May to July 2013 (Figure 5.7; MJ) are due to the packaging neck design change that was scheduled throughout the facility. Production volumes are based on sales forecast or sales demand, which are discussed in weekly meetings. If necessary, the production plan is amended to either increase or decrease production volumes. Increase of production volumes occurred before December and the Easter holiday season. Depending on the sales during the holiday seasons, the production volumes are directly affected.

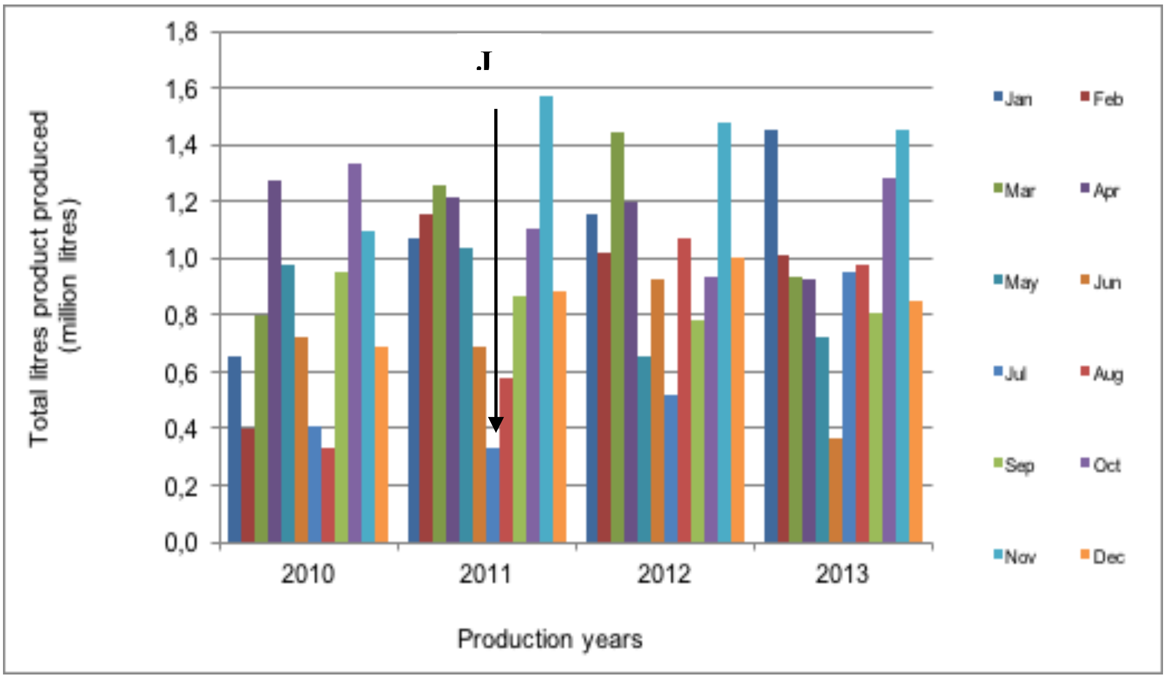


Figure 5.8: Total litres production on production sequence B for all the production years (Beverage manufacturing company data)

Figure 5.8 illustrates the December seasonal demand, where the November production volumes are more than those of December because the manufacturing facility considers the higher sales volumes in December. The month of January of each production year also shows an increase in production volumes to fill the market with products due to higher sales in the December seasonal period. The manufacturing company needs to consider the fact that increase in production can possibly lead to increase of emissions. Sequence B production volumes per year indicate a trend that December volumes are much lower than the following year's January production volumes as indicated in Figure 5.8. Sequence B produces both CSD and still beverages; however, CSD volumes are much higher than still beverage volumes. This increase is discussed below. Production in July 2011 (Figure 5.8; J) was one of the lowest production months due to a packaging design change that occurred on production sequence B. This packaging change was based on the Trade Metrology Act (RSA, 1973). The packaging size was reduced by 10 ml and therefore maintenance was scheduled for re-engineering of production sequence B.

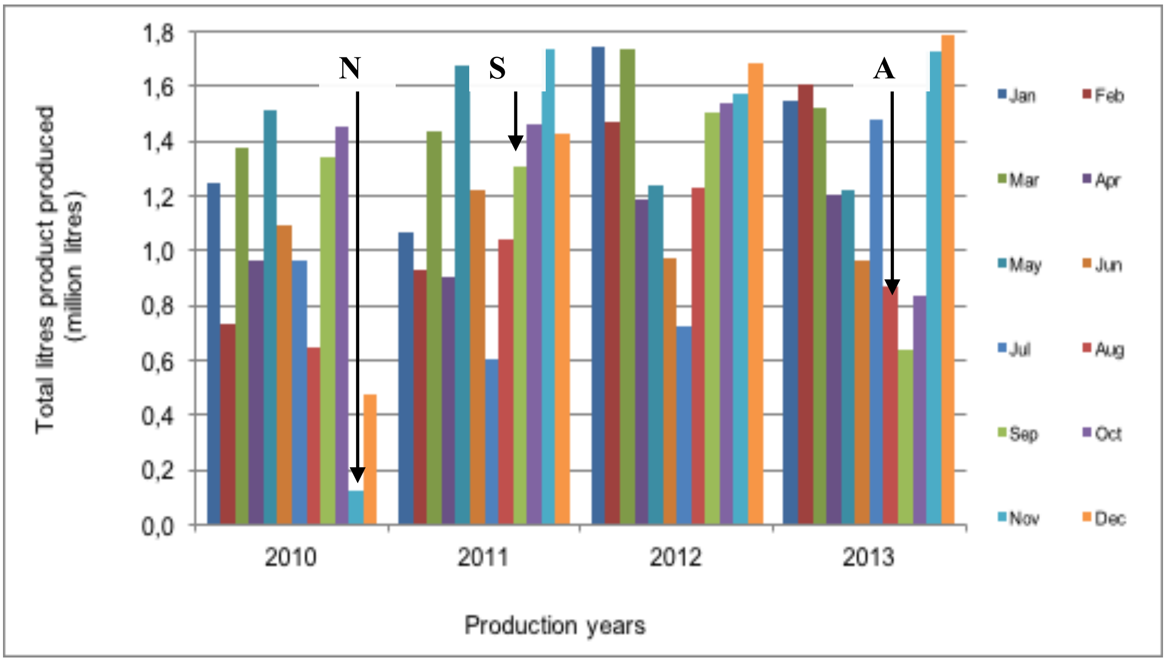


Figure 5.9: Total litres produced on production sequence C for all the production years (Beverage manufacturing company data)

Production sequence C produces both CSD and still beverages. November 2010 (Figure 5.9; N) was the lowest production month of all the months on production sequence C. Sequence C is the production line that produces less than 2 lt packaging volumes and the packaging material (bottles) is sourced from one supplier. The specific bottle supplier had a major breakdown on their production line in November 2010 and could not supply the beverage company with bottles for sequence C, hence the low production volumes.

The additional still beverage production was introduced on sequence C from September 2011 (Figure 5.9; S). It was expected that this increase in production would most probably have an effect on total emissions and water usage within the beverage company. A reduction in volumes is noted from August 2013 (Figure 5.9; A) since sequence C was the last production sequence that was changed over to the new packaging design. Once sequence C was in full production after the neck design change, production volumes increased to fill the market after the sales lost during the neck change period.

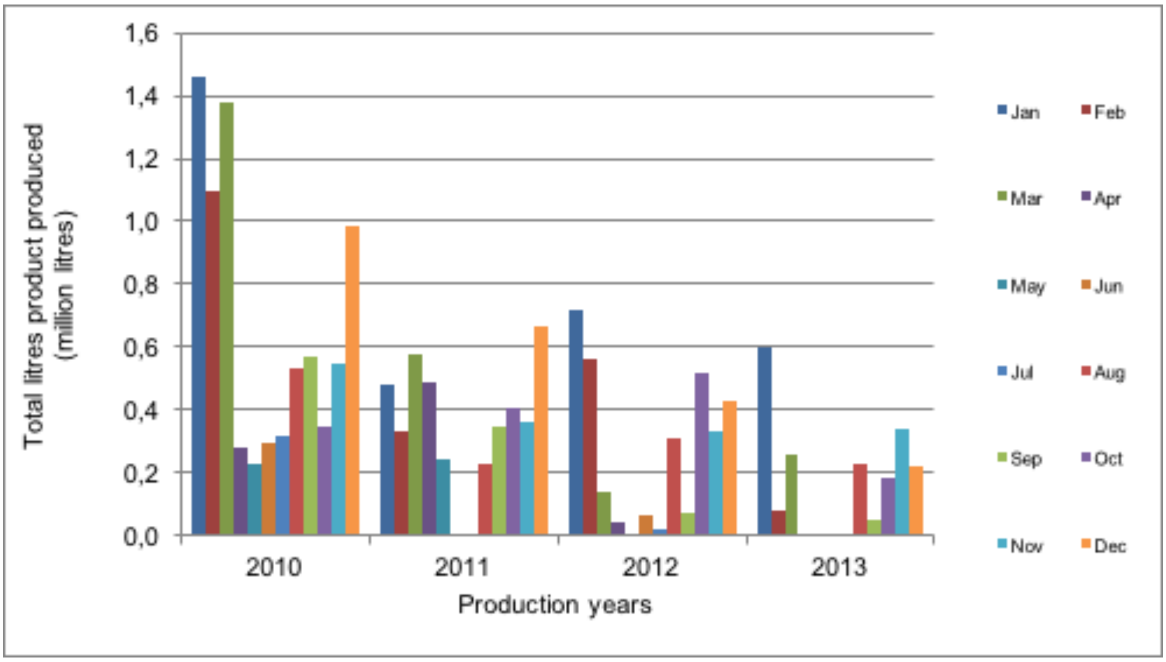


Figure 5.10: Total litres product production sequence D for all the production years (Beverage manufacturing company data)

Production sequence D indicates a substantial reduction in total annual production volumes from production year 2012. The production volumes were only scheduled once head office approved the production plan due to the fact that the decision to discontinue was made in 2011. Figure 5.10 also illustrates high production in either December or January for each year. To keep manufacturing costs low, production is scheduled once production volumes are low. A reduction in volumes is noted from year to year. The material forecast for sequence D must be well planned and managed to maintain minimal stock holding to ensure lower cost for the beverage company. The assumption is made that sequence D's contribution to emissions will be lower due to the reduction of production over the past four years. Table 5.2 provides data on sequence D's production volumes for all four production years (2010-2013).

Table 5.2: Sequence D production volumes for all four production years (Beverage manufacturing company data)

Production year	**2010**	**2011**	**2012**	**2013**
Total litres produced on sequence D	8 028 812	4 129 228	3 211 272	1 945 529

Table 5.2 illustrates the reduction in volumes from production year 2010. It seems as if production year 2013 is substantially different from the other production years. The difference can possibly be attributed to the fact that the beverage company sold the line and did not want to have vast amount of stock on hand, therefore the production planning was based on the amount of stock on hand.

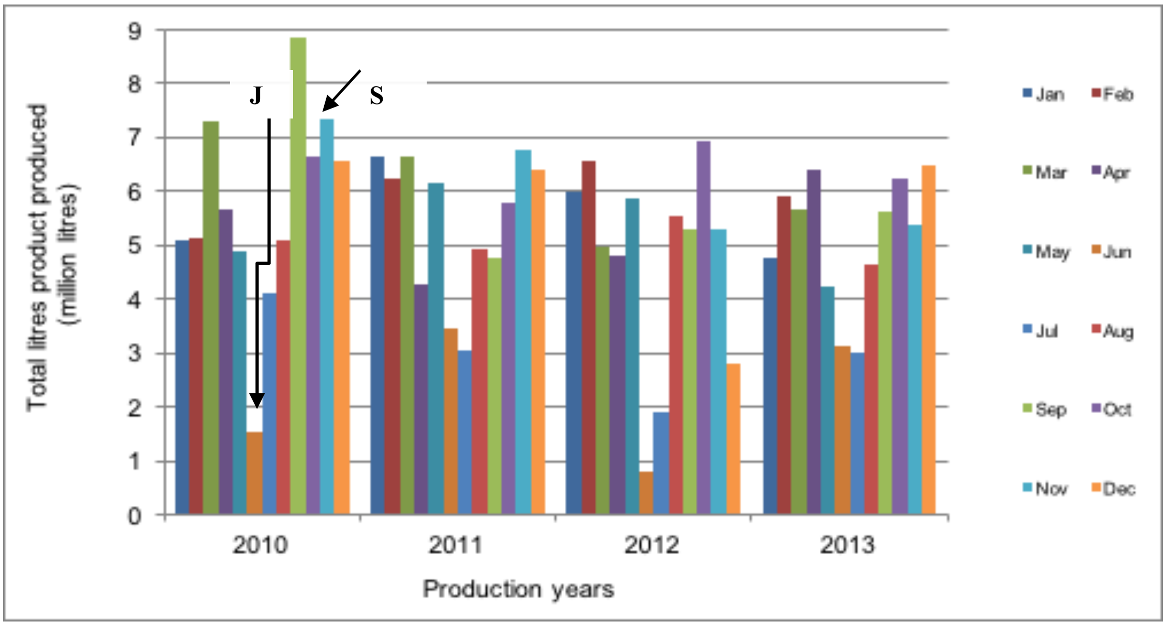


Figure 5.11: Total litres product production sequence E for all the production years (Beverage manufacturing company data)

Production sequence E produces most of the carbonated beverages within the manufacturing plant. Maintenance was scheduled in June 2010 (Figure 5.11; J) to install a new labeller on production sequence E. September 2010 (Figure 5.11; S) was the highest production month on sequence E, this was to fill the market due to the loss in production in June 2010. It took time to commission the new labelling machine that was the cause of the loss of production. July 2013 was the lowest production month for that specific year based on the maintenance that was scheduled for the new packaging bottle neck design. Production year 2010 was the year with the highest total production volumes on sequence E as per Table 5.3.

Table 5.3: Total litres production on sequence E for each production year (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Total litres produced on sequence E	68 177 696	65 083 392	56 759 196	61 409 314

Production sequence A and sequence E produce most of the CSD production within the beverage company. Statistical analysis showed that there is no significant difference between the production years of the two sequences but a significant difference between the production months ($p<0.0001$; Appendix G). This conclusion is important in terms of electricity usage because sequence E electricity usage is much more than sequence A (personnel communication, engineering manager, August 2014).

5.3 CARBONATED BEVERAGE PRODUCTION VOLUMES

Section 5.2 above illustrates the total volumes produced within the beverage manufacturing company. Most of the production volumes within the beverage plant are based on carbonated soft drink beverages (CSD) and still beverage production volumes are much lower than CSD volumes. Figure 5.12 illustrates only the CSD production volumes within the beverage plant.

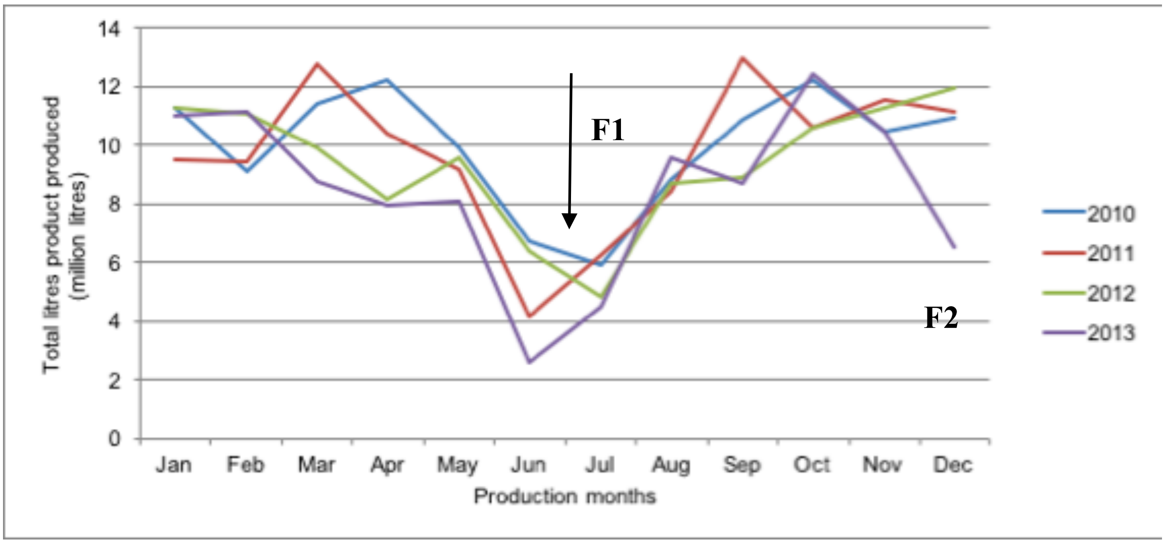


Figure 5.12: Total litres CSD beverage production per month per production year (Beverage manufacturing company data)

As per Figure 5.12, the production volumes for all four years are lower in the winter months than most of the summer months (Figure 5.12; F1). Statistically it was also determined ($p = 0.616$) that in the winter months production volumes are much lower than in the summer months. Another contribution to the lower volumes is that the neck packaging change maintenance was scheduled on production sequence A, B, C and E during the winter months. It is noted that in December 2013 (Figure 5.12; F2) was the lowest production volumes for all December months analysed and this was due to electricity shortages from the country's electricity supplier. Production was planned as per production plan, but volumes could not be achieved due to the shortage of electricity. Table 5.4 provides the CSD production volumes for all four production years.

Table 5.4: CSD production volumes for all four production years (Beverage manufacturing company data)

Production year and month	**2010**	**2011**	**2012**	**2013**
Jan	11 306 480	9 524 908	11 303 861	10 986 800
Feb	9 122 950	9 437 805	11 095 070	11 114 215
Mar	11 434 900	12 748 430	9 893 590	8 783 501
Apr	12 206 980	10 365 345	8 160 811	7 912 784
May	9 929 060	9 180 828	9 564 968	8 061 337
Jun	6 751 288	4 161 690	6 418 062	2 585 173
Jul	5 907 302	6 232 440	4 823 889	4 449 266
Aug	8 833 022	8 449 618	8 661 582	9 546 182
Sep	10 873 230	12 977 788	8 901 967	8 660 431
Oct	12 197 146	10 611 608	10 618 414	12 415 253
Nov	10 425 119	11 547 766	11 248 176	10 440 889
Dec	10 944 358	11 166 814	11 966 333	6 488 775
Total litres produced	119 931 839	116 405 044	112 656 727	101 444 609

The lowest CSD production volumes were achieved in either June or July of each production year (Table 5.4). This finding is also indicated by statistical analysis (Appendix E). The manufacturing plant must consider the lower production months when production planning and forecasting is discussed with the sales team. It is also an opportunity for the beverage plant to schedule the preventative maintenance during the winter months.

The CSD production volumes indicate a reduction over the four production years as per Figure 5.13. Figure 5.13 illustrates the CSD beverage production with very similar seasonal production cycles each production year, therefore the assumption can be made that the volumes are linked to customer and seasonal demand. Figure 5.13 also illustrates that production in the summer months is higher than in the winter months; thus the assumption is made that consumers prefer cold beverages in the summer months rather than in the winter months.

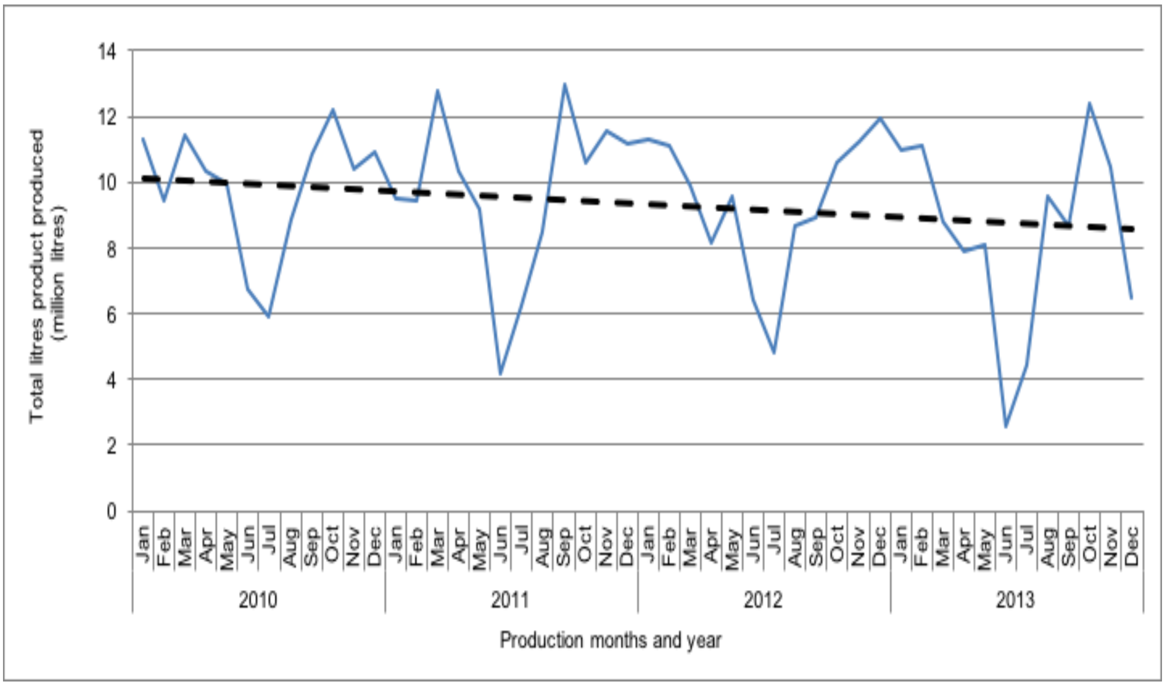


Figure 5.13: Total litres product produced based on the low and high CSD production months per production year (Beverage manufacturing company data)

The beverage plant should consider the fact that reduction is noted from year to year. The beverage plant should manage production efficiency to ensure the optimal production volumes are achieved with minimal wastage of resources to prevent unnecessary emissions, for example electricity usage when some of the production lines are not in operation.

5.4 STILL BEVERAGE PRODUCTION VOLUMES

The main difference between still beverages and carbonated beverages is that in still beverages nitrogen is used as a raw material and not carbon dioxide. The still beverage production volumes are much lower in comparison with carbonated beverage production volumes as indicated in Table 5.5.

Table 5.5: Total litres CSD and still beverages volumes (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Total litres CSD beverages	119 931 839	116 405 044	112 656 727	101 444 609
Total litres still beverages	3 688 330	8 955 510	13 490 910	11 864 260

The trend of still beverage production over the four production years is not as clear as the trend for carbonated beverages. An increase of production is noted for production year 2011 (from August 2011) and 2012 and then a reduction in production year 2013. Figure 5.14 indicates the still beverage production over the four years.

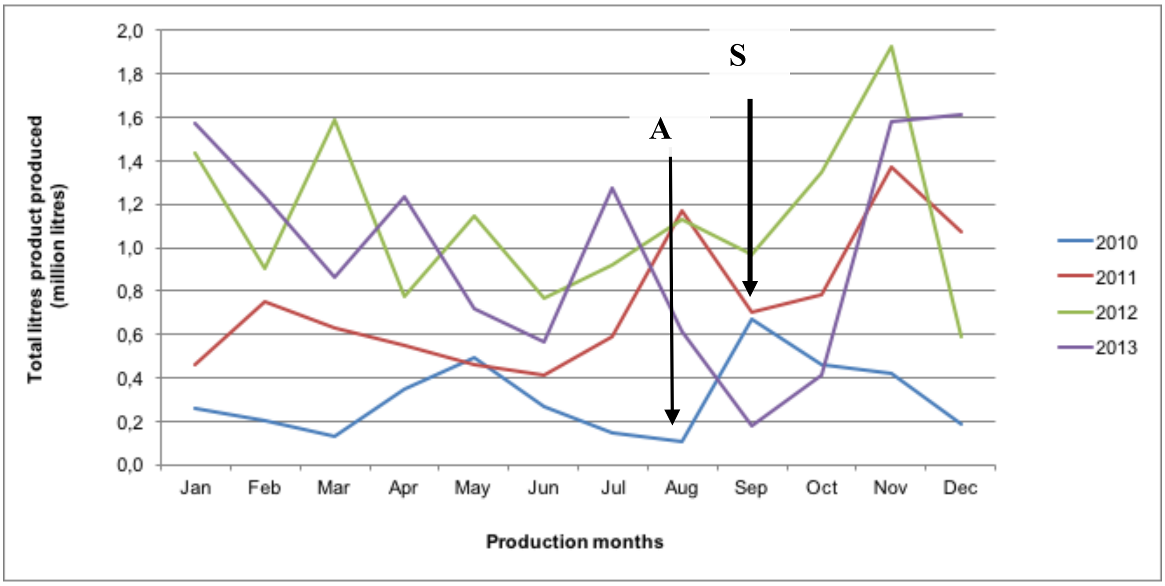


Figure 5.14: Total monthly still beverage production per production year (Beverage manufacturing company data)

The lowest still beverage production was noted in August 2010 (Figure 5.14; A) due to the packaging design change as per the Trade Metrology Act (1973) on sequence B. Still beverage was only produced on sequence B in 2010 and the first part of 2011. In September 2011 (Figure 5.14; S), sequence C was commissioned to include still beverage production. Maintenance was scheduled on sequence C for the installation of a new flush pasteurising unit that is required for the production of still beverage on sequence C.

The production on sequence B in June 2011 was the lowest production month for 2011, due to the packaging design change based on the Trade Metrology Act (1973). Preference was given to CSD production during this time on sequence B and therefore minimal production was scheduled for still beverages during this time. Table 5.6 indicates that production year 2012 was the production year with the highest still beverage production volumes.

Table 5.6: Still beverage production for each production year (Beverage manufacturing company data)

Production year and month	2010	2011	2012	2013
Jan	255 120	460 350	1 435 930	1 569 710
Feb	199 870	751 290	899 920	1 234 590
Mar	128 350	629 120	1 591 660	862 390
Apr	348 220	547 280	771 290	1 234 690
May	488 830	463 300	1 148 970	719 150
Jun	270 080	***415 790***	765 420	564 120
Jul	147 300	586 570	923 330	1 276 760
Aug	***102 620***	1 166 490	1 128 740	615 650
Sep	672 290	705 760	***965 440***	177 610
Oct	463 950	786 020	1 345 990	413 340
Nov	422 440	1 373 320	1 925 830	***1 582 040***
Dec	189 260	1 070 220	588 390	1 614 210
Total litres still beverages	3 688 330	8 955 510	13 490 910	11 864 260

The approval to produce still beverages on sequence C was effective in September 2011 and it is noted that more still beverages were produced on sequence C as from production year 2012 than on sequence B. In August 2013 still beverage production on sequence C was moved to another production facility site and the reduction in volumes can be noted as per Table 5.6. The commissioning of the new facility production sequence did not meet the project time sequence and still beverages were moved back to sequence C in November 2013 and an increase in volumes is noted. In November and December 2013 an increase is noted on sequence C because the new sequence commissioning in the other facility was delayed and production was scheduled on sequence C to ensure sufficient products in the market for customer consumption.

A possible reason for higher production volumes on sequence C is that customers preferred products produced on sequence C based on the type and size packs. Sequence B produces less than 500 ml single serve units and sequence C produces more than 500 ml, which is a multi-serve unit. A multi-serve unit can be shared by more than one person, which makes it more cost-effective for the customer. Figure 5.15 illustrates the total still beverage production on both sequence B and sequence C.

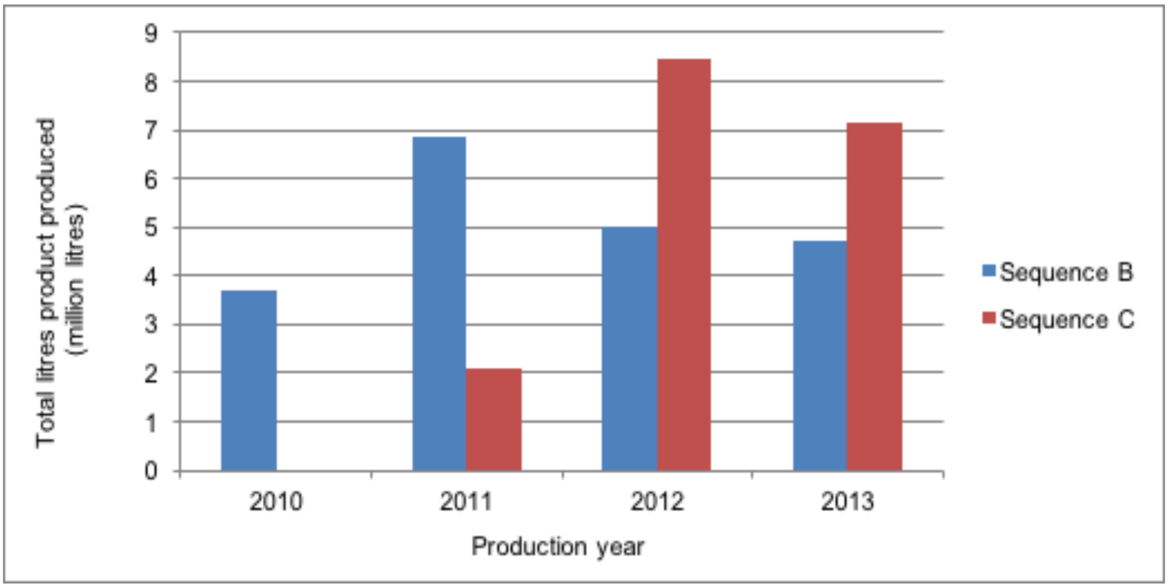


Figure 5.15: Total litres still beverage production between sequences B and sequence C for each production year (Beverage manufacturing company data)

One-way ANOVA was conducted to determine whether there is any significant difference between the production years and months for the total still beverage production (Appendix H, Figure 5.16). The Tukey HSD test was performed and it is noted that there is no significant difference between production years 2011 and 2012, neither between 2011 and 2013 or production years 2012 and 2013. There is a significant difference between the following:

- ❖ Significant difference at the 5% confidence level between production years 2010 and 2011
- ❖ Significant difference at the 1% confidence level between production years 2010 and 2012
- ❖ Significant difference at the 1% confidence level between production years 2010 and 2013

This information confirms that the still beverage production increased when sequence C was scheduled to produce still beverage products. Figure 5.16 illustrates the lower production volumes in production year 2010 against the rest of the production years.

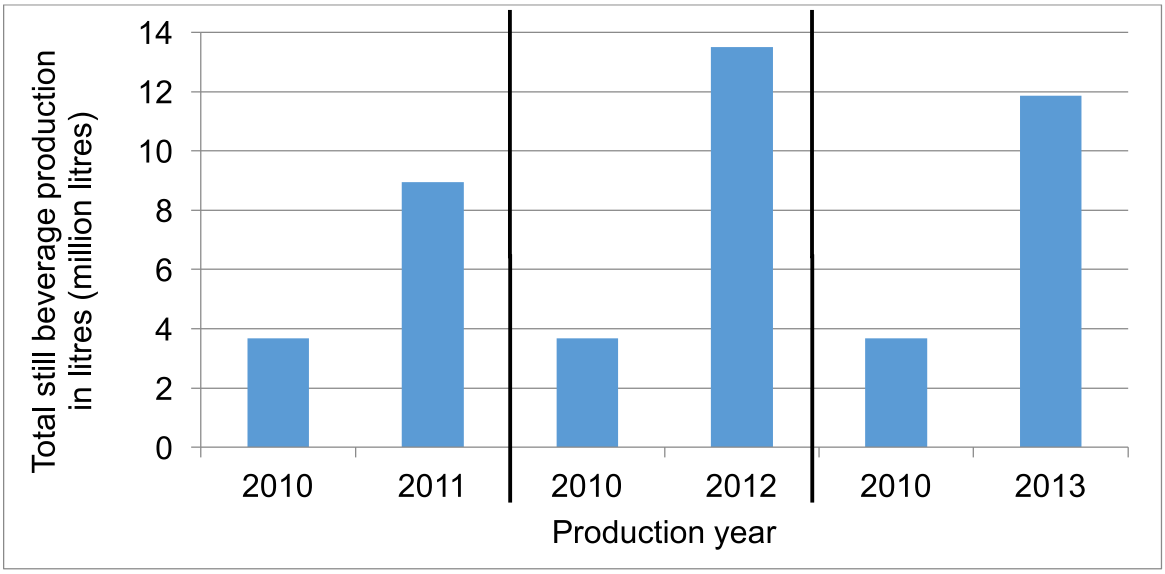


Figure 5.16: Significant differences between still beverage production years for total production volumes are illustrated by aid of a bar chart (Beverage manufacturing company data)

It is an indication that if only one sequence is scheduled to produce still beverages the production volumes will be much lower than when production is scheduled on both lines, which is directly related to sales forecast and customer demand.

5.5 CARBON FOOTPRINT

5.5.1 INTRODUCTION TO CARBON FOOTPRINT

The various emission sources that contribute to the beverage manufacturing company are illustrated in Figure 4.2 in Chapter 4. The carbon footprint is calculated based on the secondary data (Appendix C) received from the beverage manufacturing company and through conducting interviews with employees.

5.5.2 VALIDATION PROGRAMMES

Results show that the data on the overall carbon footprint of a product will vary according to the accounting methodology used (Brenton *et al.,* 2010). When discussing carbon footprints, users should declare the level of the data collection that accompanied their calculation. This should include statements as to whether or not any primary data were collected in a different country that are to be used for benchmarking purposes (Brenton *et al.,* 2010).

Although BIER and the South African Wine Industry apply different methods of calculation, the PAS 2050:2011 is the only standard that both parties cite in their calculations. While the guidelines from PAS 2050:2011 and the latest 100-year global warming potential values for GHGs were applied for the purpose of calculating the carbon footprint for this study, additional guidelines were also considered (BSI, 2011). PAS 2050:2011 was published by the British Standards Institution (BSI) at the end of 2008 and the latest update in use is 2011 (BSI, 2011). To date, it is the most detailed and comprehensive set of guidelines for the calculation of product-based carbon footprints publicly available. The PAS 2050:2011 method used to calculate carbon footprints can be used by companies to guide their own management activities or they can be communicated to consumers via a carbon label. PAS 2050:2011 states that IPCC guidelines should be followed for calculating emissions from agriculture and land use change, both of which are relevant to food product carbon footprint. The IPCC emission guidelines are only updated every six years and Defra updates emission guidelines yearly (Defra, 2013). Therefore, Defra emission factors for each production year were used for the current study.

5.5.3 IN-HOUSE EMISSION DATA CLASSIFICATION

As far as possible, the process of data collection and analysis was transparent and it engaged various levels of the organisation to ensure that the in-house data and results were accurate.

As per BIER (2011), the performance data must be measured, recorded, tracked and reported in accordance with the following guiding principles:

- Relevance: Data must appropriately reflect the operations.
- Completeness: Report all performance data and provide explanations for any reporting deviations.
- Consistency: Provide meaningful performance data over time.
- Transparency: Information should be provided on relevant assumptions and the accounting and calculation methodologies as well as data sources used for reporting performance data.
- Accuracy: Data must not contain material errors and must enable users to make decisions with reasonable assurance regarding the integrity of the reported information.
- Measurability: The data required to support completion of an inventory should be readily available or made available within reasonable time and/or cost. Any exclusion of emission sources shall be justified and disclosed.

Many carbon footprint data collection and analysis methods require the use of generic data, such as emissions from energy generation, emissions from soils and emissions from land use change and transport (Brenton *et al.,* 2010). However, because of the nature of the available data, analysts are forced to use the best available data for a region without really knowing how valid these data are to the specific case being analysed (Brenton *et al.,* 2010).

The carbon and water footprint will be calculated on the functional unit of 1litre of beverage produced in the manufacturing plant; therefore the functional unit is based on unit produced and not on unit consumed. The approach that was taken was first to analyse the data from sources that emit the most GHGs, such as carbon dioxide. The sources that are seen as a service to the entire beverage manufacturing, such as the boiler, were analysed last.

5.6 CARBON EMISSIONS: SCOPE 1

5.6.1 CARBON DIOXIDE VOLUMES

Carbon dioxide is sourced from a supplier, which is based in Sasolburg in the Free State province. The supplier plant sources raw CO_2 from refinery suppliers and uses a scrubbing process to purify the CO_2 to reach 99.9% purification. The raw gas is pre-cooled and compressed in the scrubbing process. The second process takes place in the catalytic oxidation unit. During the catalytic oxidation process hydrocarbons are removed and a humidifier removes water that is trapped in the raw gas. A dehydrator and activated carbon filter dries the gas and removes alcohols and aldehydes. Further purification processes follow where the gas is cooled until it is deemed ready for use (Afrox, 2013). Another method of manufacturing CO_2 is by burning fuel and the gas is absorbed into a mono-ethanolamine-based solution, which is heated by a combustion process to release the raw CO_2 gas (TPI, 2012).

Carbon dioxide is used as a raw material only in carbon dioxide beverages and not in still beverages production. The loss of CO_2 in the beverage manufacturing process is based on the amount of CO_2 received from the supplier and the actual amount of CO_2 used in the beverage processing facility as indicated in Figure 5.17.

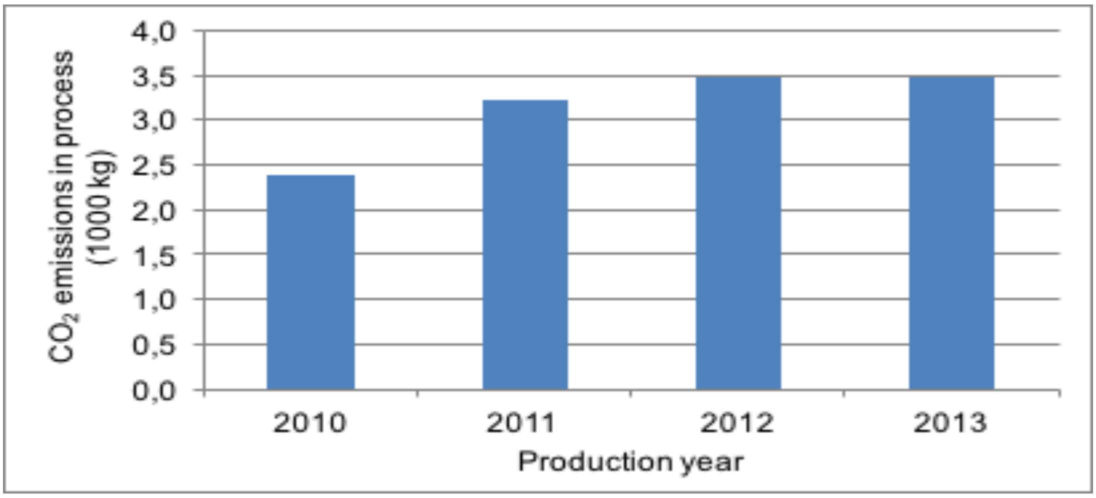


Figure 5.17: Total CO_2 loss in the process for production years 2010–2013 (Beverage manufacturing company data)

As per Figure 5.17, the highest CO_2 emissions of all the production years were that of 2012. The emission data presented in Figure 5.17 were sourced from the inventory management system which indicates the amount of CO_2 received from the supplier and the amount of CO_2 used during the production process. The difference between the CO_2 received and CO_2 usage is the actual CO_2 loss during the production process, and these are the CO_2 gas emissions illustrated in Figure 5.17

In March 2011 (Figure 5.18; M) a leaking valve was noted at the CO_2 storage tanks and the cooling system at the storage tanks was not working efficiently. If the cooling system does not work as per supplier specifications, the CO_2 stays in the gas phase and does not enter the liquid phase, which causes the safety valve to release CO_2 into the atmosphere. The CO_2 storage tanks contain an evaporation system and the blowers of the system force the ambient air to the surface of the vaporising tubes. During this process the CO_2 is heated. This system is linked to a low temperature switch that is at the outlet of the CO_2 pipelines to prevent the external surfaces of the evaporation tubes from freezing. When the system freezes, the switch forces the system open and CO_2 is released into the atmosphere (TPI, 2012). Figure 5.18 indicates the CO_2 loss into the atmosphere due to blow off and the CO_2 lost in the production process.

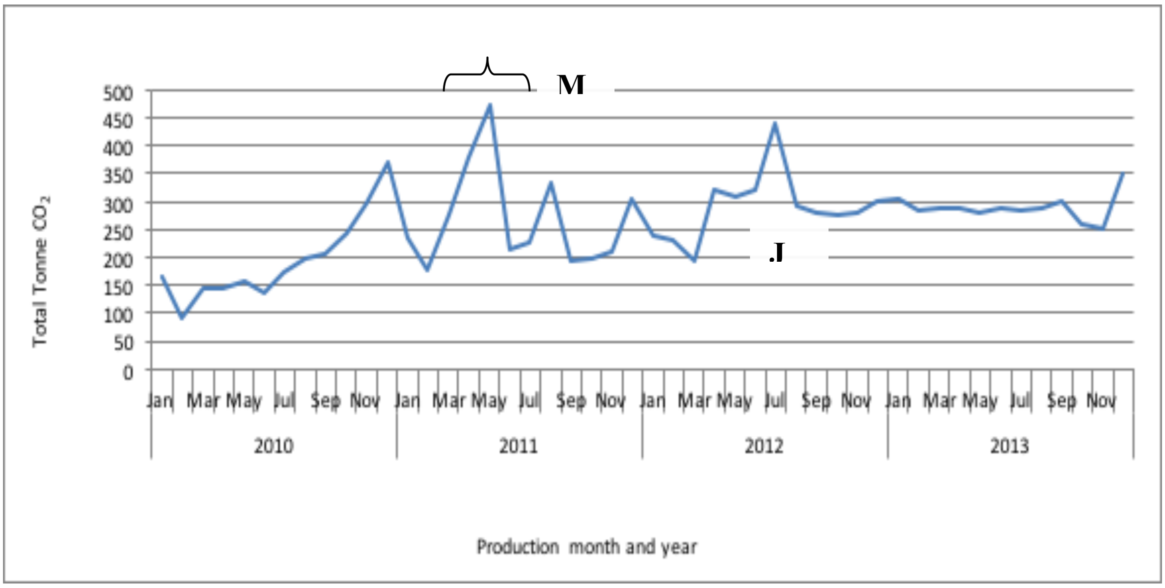


Figure 5.18: Total tonne CO_2 loss in the process for each production month and year (Beverage manufacturing company data)

The increase in CO_2 lost due to the faulty evaporation system is noted as from March 2011 until June 2011. The manufacturing company installed an additional storage tank in July 2012 (Figure 5.18; J) and the increase in CO_2 loss was due to the commissioning of the storage tank. Figure 5.19 illustrates the CSD production and the CO_2 lost within the production years.

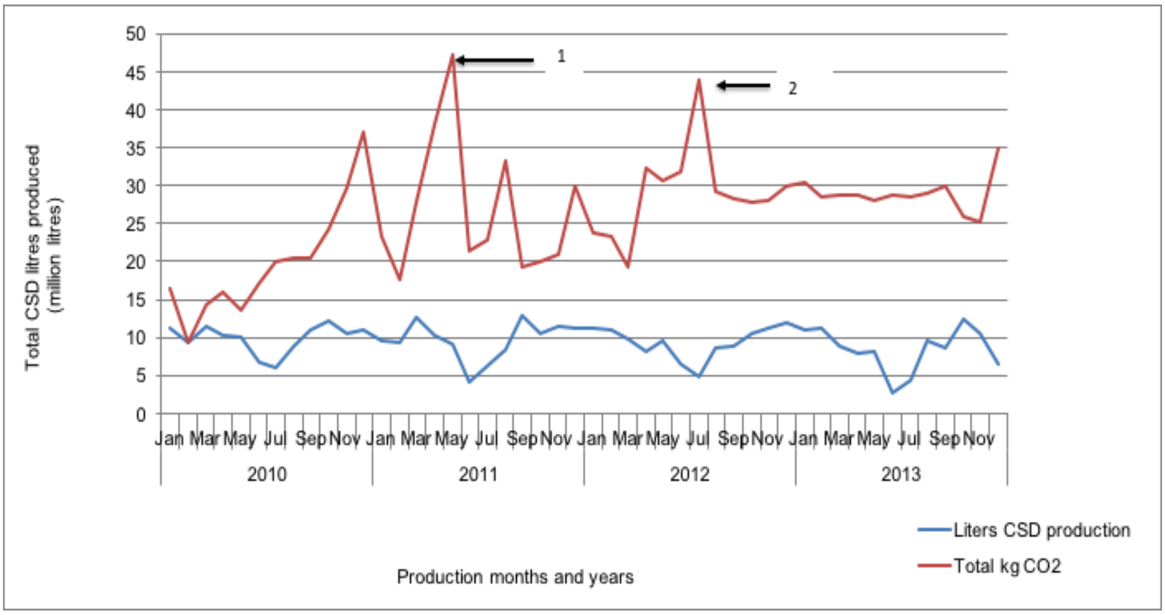


Figure 5.19: Total litres production of CSD beverages and total loss of CO_2 (Beverage manufacturing company data)

A possible reason for the lower CO_2 loss in 2010 is that no maintenance projects were planned for production year 2010 in the production plant or at the storage tanks. Figure 5.19 (1&2) shows that each time maintenance work was planned in June or July for production years 2011 and 2012, the CO_2 loss is higher than actual production. The reason relates to the safety switch on the CO_2 tanks as explained. The pressure built up in the tank forces the safety valve to release CO_2 into the atmosphere.

Table 5.7: Total litres CSD production and total CO_2 loss (Beverage manufacturing company data)

Production year	**2010**	**2011**	**2012**	**2013**
Total CO_2 loss in kg	2 038 646	2 476 888	2 156 182	1 698 593
Litres CSD produced	119 931 839	116 405 044	112 656 727	101 444 609

One-way ANOVA was done to determine whether there is a significant difference between CSD production volumes and CO_2 usage per each year (Appendix I). The conclusion is that there is no significant difference at the 5% level between years ($p = 0.201$). This is an indication that the CSD production and the CO_2 usage are closely related for the four production years. If there was an increase in CSD then an increase in CO_2 was noted and vice versa. This would give an indication to the beverage company when higher CO_2 usage could be expected.

The emission information was sourced from the inventory management system and from the ISO 14001 aspect register. As per Defra (2010; 2011; 2012; 2013) yearly emission factors the Global Warming Potential Factor (GWP) for CO_2 equals one.

Emission type	**Global Warming Potential Factor**
CO_2	1 GWP

The GWP factor is 1 for all four production years and the total usage as indicated in Table 5.8.

Table 5.8: Scope 1: CO_2 emissions (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Total usage kg CO_2	2 386 454	3 218 103	3 483 147	3 467 303
Emission factor	1.00	1.00	1.00	1.00
Litres CSD produced	119 931 839	116 405 044	112 656 727	101 444 609
kg CO_2e / litre unit produced	0.01989	0.02764	0.03091	0.03417
g CO_2e /litre unit produced	19.89	27.64	30.91	34.17

It is noted that production year 2010 is the year with the lowest CO_2 emissions lost as well as the lowest g CO_2e per litre unit produced. Production year 2013 was the year with the second highest usage of CO_2 but the highest in terms of g CO_2e per litre unit produced. A possible explanation can be that in production year 2013 the production was lower as a result of all the down time on the production lines. Even though production was lower, the CO_2 was still emitted into the atmosphere by CO_2 release at the CO_2 storage tanks and also through CO_2 loss within the production facility. The beverage manufacturing process is of such a nature that even if production is lower or if no products are produced, CO_2 is still lost in the production process.

5.6.2 LIQUID PROPANE GAS VOLUMES

All forklifts used on the manufacturing site are driven by LPG and are the property of the manufacturing company. The gas will ignite and burn instantly and is a fire and explosion hazard. Since LPG is heavier than air, it will collect in dust and drains (Afrox, 2015). The LPG usage is calculated over the total production period because the forklifts are used throughout the entire process. The manufacturing company has a nine-tonne LPG tank on site and the forklift cylinders are filled from the nine-tonne tank. No information was available for August and December 2011. The usage per litre product produced was calculated for the other known 2011 months to predict the LPG usage for August and December 2011.

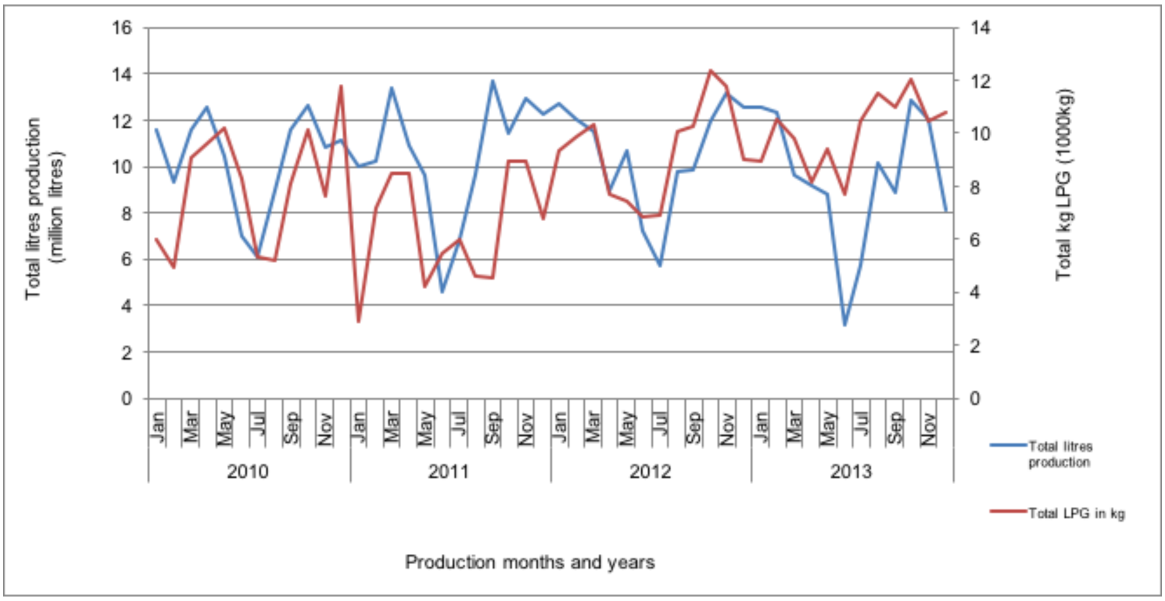


Figure 5.20: Total litres production and kilogram LPG usage for production years 2010–2013 (Beverage manufacturing company data)

During the interviews with the beverage manufacturing company managers, no reason could be given for the lower LPG usage in some of the production months in 2011 (see Figure 5.20). It is possible that the lower usage is due to the calculation that was made for the information that was not available for the entire production year 2011. The LPG usage increased in production year 2012 because the manufacturing company increased the number of forklifts within the processing facility due to the increased storage capacity of the final warehouse on site. This increase can be seen from August 2012 through to production year 2013. Figure 5.21 indicates the total kilogram LPG gas used for all four production years.

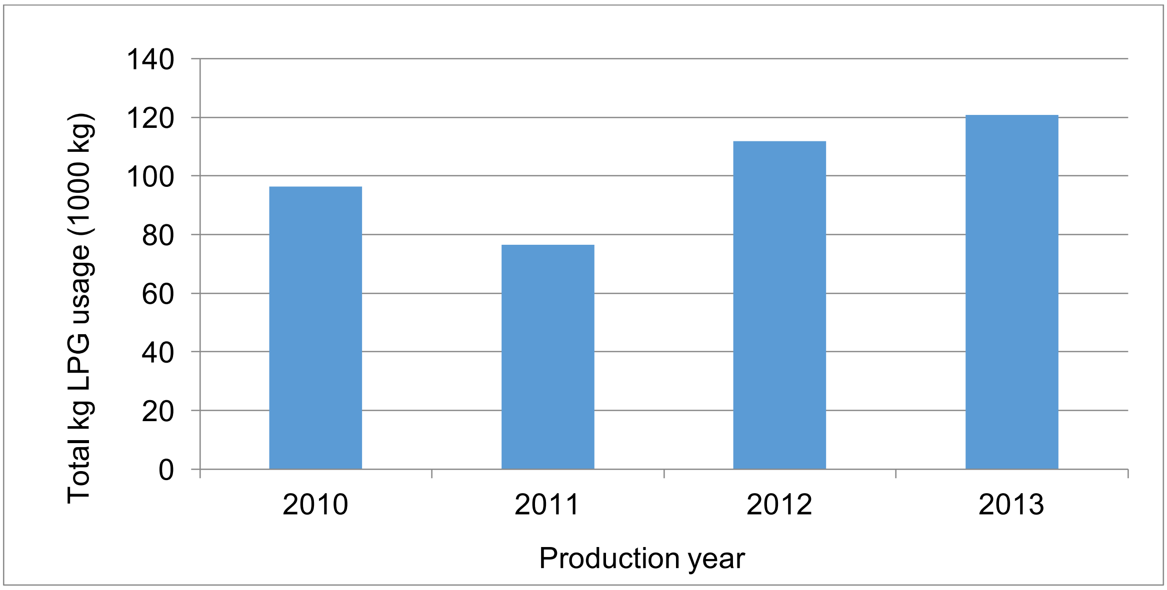


Figure 5.21: Total kilogram LPG usage per production year (Beverage manufacturing company data)

One-way ANOVA was conducted to determine whether there is a significant difference between the LPG usages against the total litres produced for the four production years (Appendix J). The conclusion is that there is a significant difference between years at the 5% confidence level for percentage of LPG usage (p=0.001). The Tukey HSD test was conducted in an attempt to understand where the significant difference is. It is noted that there is only a significant difference between production year 2010 and 2013 at a 5% confidence level and a significant difference between 2011, 2012 and 2013 production years at a 1% confidence level. This confirms that more LPG gas was used during the increase of the warehouse capacity. Figure 5.22 illustrates the significant differences of LPG usage between each production year.

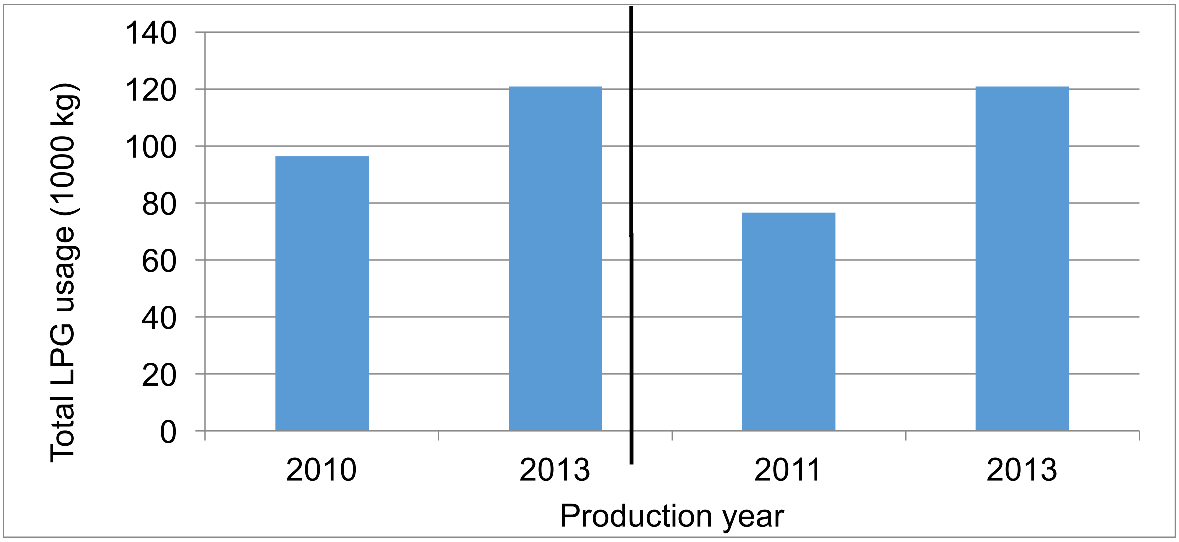


Figure 5.22: Significant differences between production years for LPG usage (Beverage manufacturing company data)

The information gathered for the LPG emission calculation was from the inventory management system and the ISO 14001 aspect register. As per Defra yearly Fuel emission factors, the following factors for LPG were used for Scope 1 calculations.

Emission type	**Factor**
2010 LPG emission factor	1.4951 litres
2011 LPG emission factor	1.4884 litres
2012 LPG emission factor	1.5326 litres
2013 LPG emission factor	1.4929 litres

The manufacturing company measures the LPG in kilograms and the emission factors in litres. The conversion was done from kilograms to litres by using the conversion factor of 522.4 (Defra, 2012) to ensure that the Scope 1 calculations are as per Defra guidelines. Table 5.9 indicates the conversion from kilograms to litres as well as the emission calculations per production year. The Scope 1 calculation for each year is the total CO_2e emissions.

Table 5.9: Total LPG emissions per production year (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Total LPG in kg	96 296	71 286	111 895	120 790
Convert kg LPG to litres LPG	522.40	522.40	522.40	522.40
Total LPG in litres	184.33	136.46	214.20	231.22
Emission factor LPG in litres	1.4951	1.4884	1.5326	1.4929
Total CO_2e kg / LPG	275	203	328	345
Total litres production	123 620 169	125 360 554	126 147 637	113 308 869
Total CO_2e kg / litre unit produced	0.0000022	0.0000016	0.0000026	0.0000030
Total CO_2e g / litre unit produced	0.0022	0.0016	0.0026	0.0030

The total litres production in 2013 was much lower than in any other production year but the LPG g CO_2e per litre unit emissions is the highest for this production year. During 2013 the on-site finished goods warehouse used more forklifts due to the increase in warehouse storage capacity. In August 2012 the manufacturing company decided that the manufacturing company finished goods warehouse would be used to store finished goods from other production facilities within the group. The additional goods that were stored were dry food products and not beverages. Since different types of goods were stored in these facilities, the carbon footprint could not be determined for the carbonated beverages only but also had to include the dry goods. This resulted in an increase in the LPG usage for the finished goods warehouse. Split data sets for the amount of LPG usage for the additional finished goods in the warehouse were not readily available at the time of the study and therefore the LPG consumption was calculated for all LPG activities during this period. The forklifts used by the manufacturing company are not all designated to a specific area but can be used throughout the organisation.

5.6.3 BOILER FUEL AND NATURAL GAS

The boiler generates steam for various processes used in the manufacturing plant, namely the CIP process, the sequence B tunnel pasteuriser and the sequence C flush pasteurisation unit. In May 2011 the heavy fuel oil (HFO) boiler was changed to a natural gas boiler. The main decision for converting the HFO boiler to a natural gas boiler was based on environmental considerations and cost. The conversion from an HFO boiler to a natural gas boiler saves up to 25% kWh per unit energy produced (UKRA, 2008).

Data to split the boiler usage between CIP for all the production sequences and steam usage for the still beverage production on sequence B and sequence C were not readily available, therefore the calculations were made on total litres produced and some reference to still beverage volumes. The data for HFO were measured in litres and for natural gas in gigajoules (GJ). Both the sets of data were converted to kWh to ensure that the unit of measure were the same and comparable. The conversion factor 11.4 was used to convert HFO fuel to kWh (Enviros, 2000) and factor 277.77 to convert GJ to kWh (Defra, 2010). There were no data available for natural gas for January–April 2012 (Figure 5.24) from the beverage manufacturing company data. The emission calculations were done on total production produced within the manufacturing facility even though in some cases reference is made to still beverage production to explain the possible usage increase. Figure 5.23 indicates the amount of boiler fuel and natural gas that was used versus the total litres of production for production years.

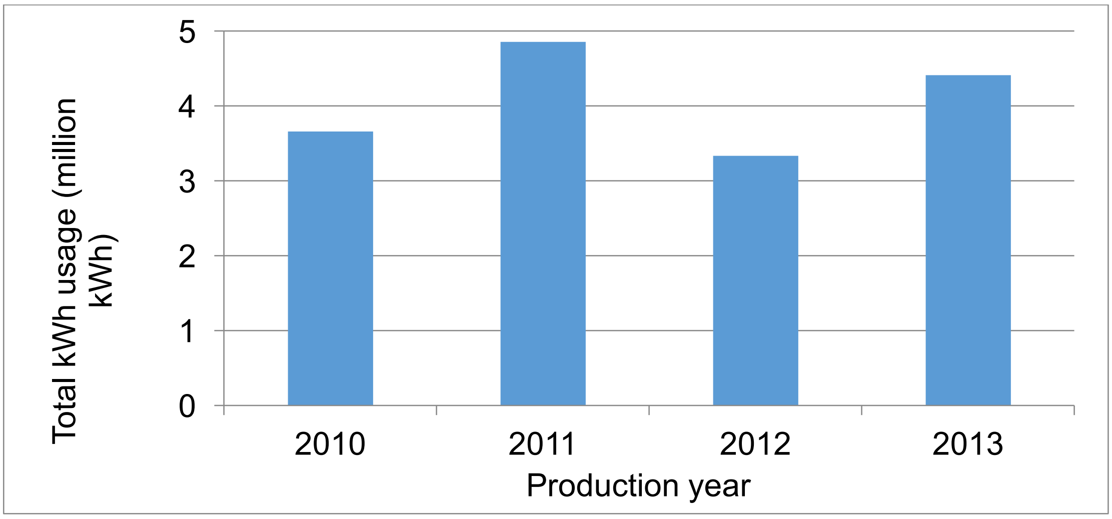


Figure 5.23: Total kWh boiler fuel and natural gas usage per production year (Beverage manufacturing company data)

The energy usage was the highest in production year 2011. Considering the increase in still beverage production on sequence B and C, it is a possible explanation for the higher usage. The beverage company must consider higher energy usage for still beverage production because CIP is conducted on a more frequent basis of every 20 hours.

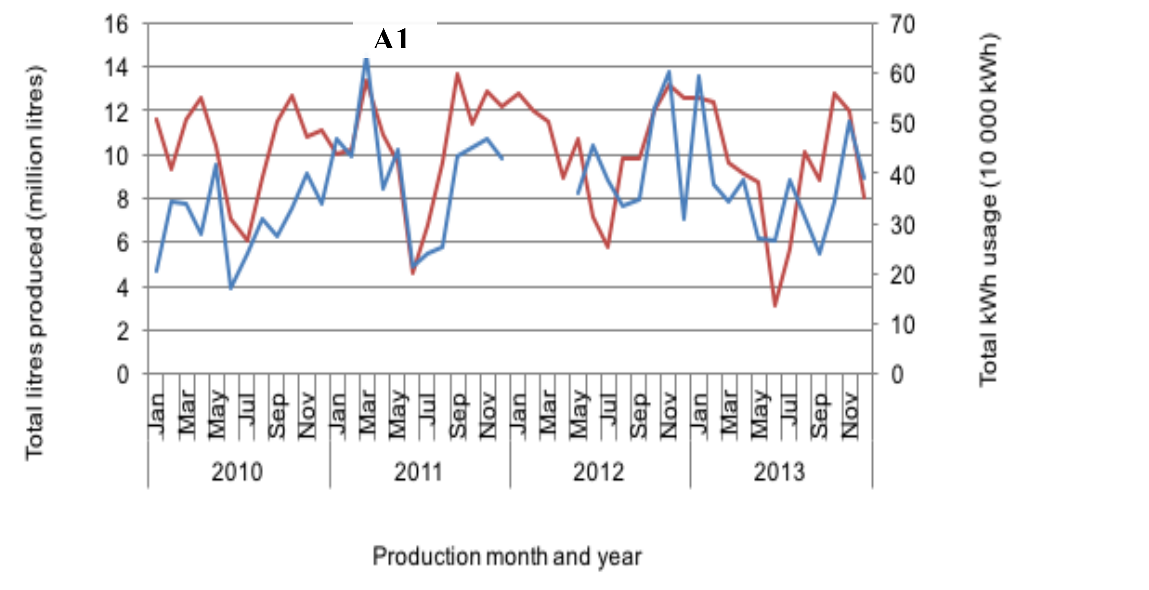


Figure 5.24: Total litres production and total kWh boiler usage for the four production years (Beverage manufacturing company data)

The total litres production is based on CSD and still beverages combined. It seems as if in production year 2010 the total energy usage for production used was less than the other production months and years considering the fact that in production year 2010 an HFO boiler was in use. In April 2011 (A1) the HFO usage and production usage are very similar; possibly because of the natural gas boiler conversion that was effected in May 2011. Figure 5.25 indicates that the natural gas energy usage is possibly more in line with total production produced. The kWh boiler usage and the still beverage production were compared in an attempt to understand whether the still beverage production and kWh usage are better aligned than total production volumes (see Figure 5.25).

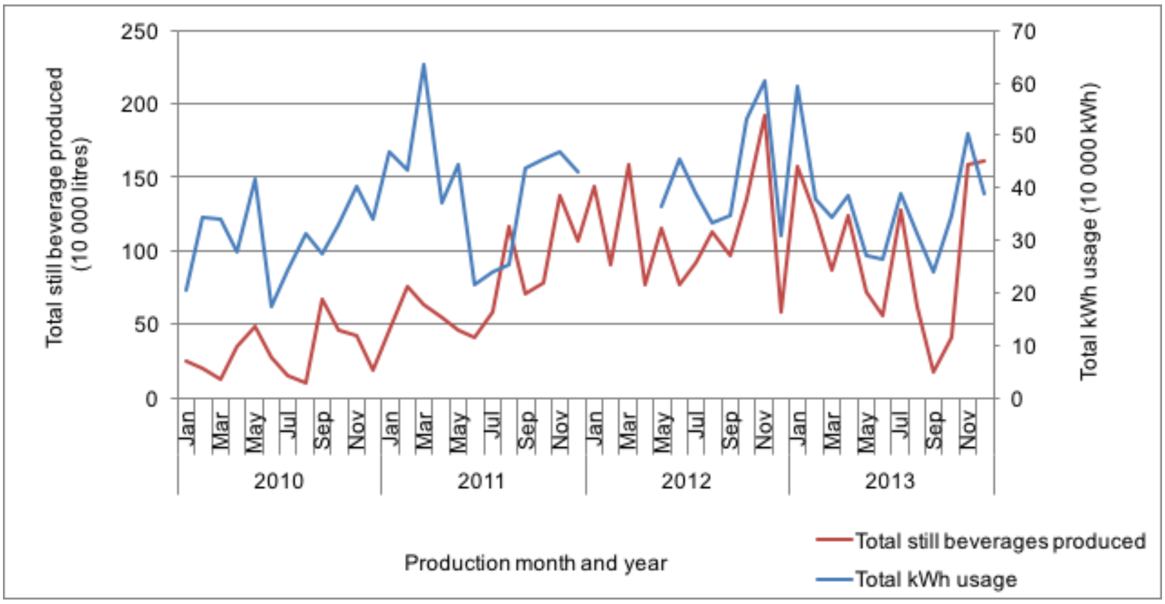


Figure 5.25: Total still beverage production and boiler usage in kWh for the four production years (Beverage manufacturing company data)

Figure 5.25 indicates that energy usage as a natural gas boiler is much more aligned with still beverage production than total beverage production. The beverage company can plan regarding natural gas usage and still beverage production. The usage will be more in line with still beverage than total beverage production. The emissions related to the boiler will be based on the planning of still beverage production. The boiler data were sourced from the ISO 14001 aspect register and captured in litres. The emission factor is noted as kWh as per Defra guidelines.

Emission type	**Factor**
2010 Fuel oil emission factor	0.28289 kWh
2011 Fuel oil emission factor	0.28451 kWh
2011 Natural gas emission factor	0.20558 kWh
2012 Natural gas emission factor	0.25981 kWh
2013 Natural gas emission factor	0.25836 kWh

The total emissions for the boiler combine the HFO and natural gas usage into one calculation to determine the Scope 1 emissions for the boiler over the four-year period as indicated in Table 5.10

Table 5.10: Total HFO and natural gas boiler emissions for the four production years (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Total kWh usage HFO	3 658 203	1 911 324	NA	NA
Emission factor HFO	0.28289	0.28451	NA	NA
Total kWh CO_2e HFO usage	1 034 869	543 790	NA	NA
Total kWh usage Natural gas	NA	2 942 973	3 331 851	4 413 765
Emission factor Natural gas	NA	0.20558	0.25981	0.25836
Total kWh CO_2e Natural gas usage	NA	605 016	865 648	1 140 340
Total kWh CO_2e HFO and Natural gas (2011)	NA	1 148 807	NA	NA
Total litres production	123 620 169	125 360 554	126 147 637	113 308 869
Total kg CO_2e per litre unit produced	0.00837	0.00916	0.00686	0.01006
Total g CO_2e per litre unit produced	8.37	9.16	6.86	10.06

Both sequence B and sequence C were producing still beverage in production year 2012 but not all the data were readily available (January–April). This year 2012 is seen to be the lowest in terms of total g CO_2e per litre unit produced. The still beverage production in 2013 is the highest. The only possible explanation for the higher g CO_2e in production year 2013 is that production volumes were much lower in June 2013 and the boiler was still in operation to ensure that the plant could produce still beverage products.

5.6.4 REFRIGERATION GAS – R22

The refrigeration gas used in the manufacturing company is mainly from the air conditioners in the administrative offices. No proper trending is in place and the data were obtained from the supplier invoices. It was noted that only 20 kg of R22 air conditioning gas was used in the last four years. The total volume produced over the four years was 488 438 102 litres and 20 kg of R22 gas did not make a difference in the Scope 1 emissions, as shown in (see Table 5.11. Therefore, R22 gas was not included as part of the emissions for the beverage manufacturing company since 0.000041 g is required to produce 1 litre of product.

Table 5.11: Total amount of R22 gas require to produce 1 litre of product (Beverage manufacturing company data)

Total production in litres for all four production years	**Total R22 gas in kg usage for the four production years**
488 438 102	20 kg
1 litre product produced	= 20/488 438 102 = 0.0000000409 kg R22 gas = 0.000041g R22 gas
R22 GWP factor	1800
Total g CO_2e R22 gas	= 0.000041 x 1800 = 0.0738 g CO_2e per litre produced

5.6.5 AMMONIA

Ammonia gas is used in the cooling systems for the processing facility and is also not recorded by the manufacturing company. The main loss of ammonia gas occurs during the drainage of oil within the cooling systems. Other losses are the initial loss during manufacturing, performance and leak testing. These losses are very small and occur once in the life of the equipment (Calm, 2002). The average lifespan of an ammonia plant is about 15 years (Metz *et al.,* 2005). The entire ammonia system is a closed system, which contributes to the minimal loss of ammonia. The total capacity of the ammonia plant of the manufacturing company is 1 tonne, which is not a very large cooling plant. The cooling system is used to cool down the carbonated beverage before the filling process starts. If carbonated beverages are not cooled down below 12^{o}C the product foams during the filling process, which causes a large amount of down time, product waste and unnecessary resource waste.

Recently designed ammonia-based systems have improved quality with respect to design and the use of material at low-temperature. However, more important is that the factory-made units or systems present a new level of quality improvement. These systems are not likely to break or release their charge in another way unless there is a human error or direct physical damage. Charge reduction has been achieved by using plate-type heat exchangers or direct expansion tube and shell evaporators (UNEP, 2003). According to the UNEP, ammonia refrigeration gas is known as R717, it has no effect on the ozone layer and has a zero GWP; therefore ammonia gas was not calculated for the Scope 1 emissions (UNEP, 2010).

5.7 CARBON EMISSIONS: SCOPE 2

5.7.1 ELECTRICITY

The electricity for the manufacturing plant is supplied by Eskom (South Africa's national electricity supplier). The manufacturing company reports electricity usage in kWh. There are two different companies on the one property; one incoming electricity meter measures electricity for the two companies (one of which is the beverage company) that reside on the one site. Based on the types of production sequences and processes in the two manufacturing companies, the engineering team calculated that the beverage company on which this study was based consumes 60% of the total incoming electricity (Personal communication, engineering manager, August 2014). Therefore the electricity data was amended to 60% usage for the beverage manufacturing company except for January 2010 to September 2010 because the other production facility only came into full operation as from October 2010. The figures for January 2010 to September 2010 represent 100% of the electricity usage bill for the site. Figure 5.26 indicates the total amount of electricity consumption considering the 60% electricity usage split.

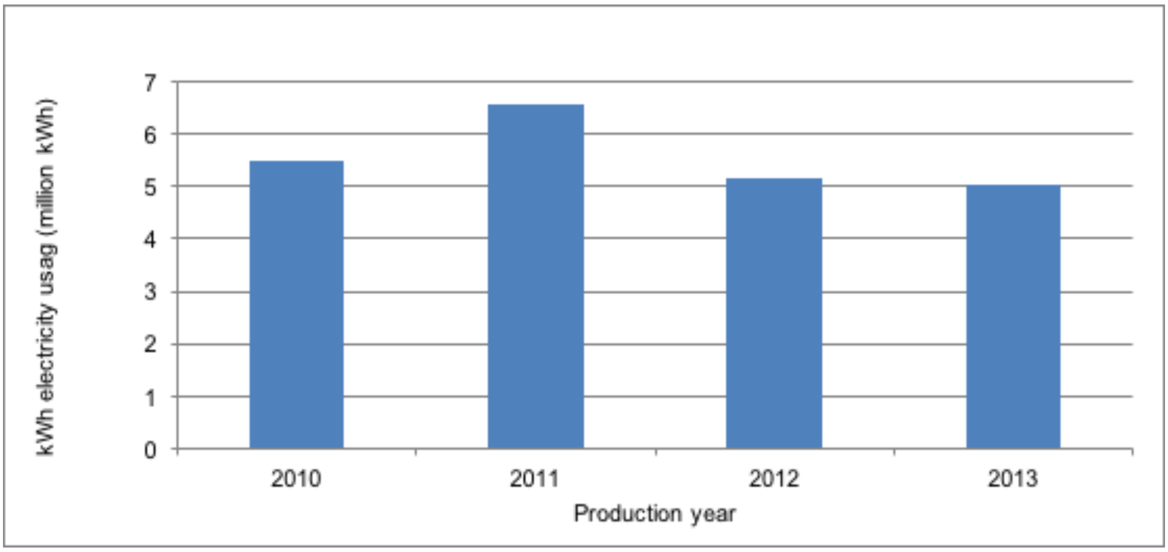


Figure 5.26: Total kWh electricity usage for production year 2010–2013 (Beverage manufacturing company data)

Figure 5.26 indicates an increase in electricity usage in 2011. A possible explanation for this increase is the growth in still beverage production on sequence B and the additional still beverage production on sequence C during 2011. The still beverage production on both sequence B and sequence C undergoes sterilisation, which requires more heat and electricity than the carbonated beverages produced on the other production sequences. Sterilisation of beverages involves heating the product to a prescribed temperature for a prescribed time. In this case the still beverages are heated to 75°C on sequence B and 94°C on sequence C. The requirement for CIP during still beverage production is much higher than for CSD production. The CIP requirement for still beverage is every 20 hours and with CSD it is every 72 hours due to the nature of CSD products. Still beverages are much more susceptible to microorganisms than CSD products. Figure 5.27 illustrates the difference between total production volumes and electricity usage.

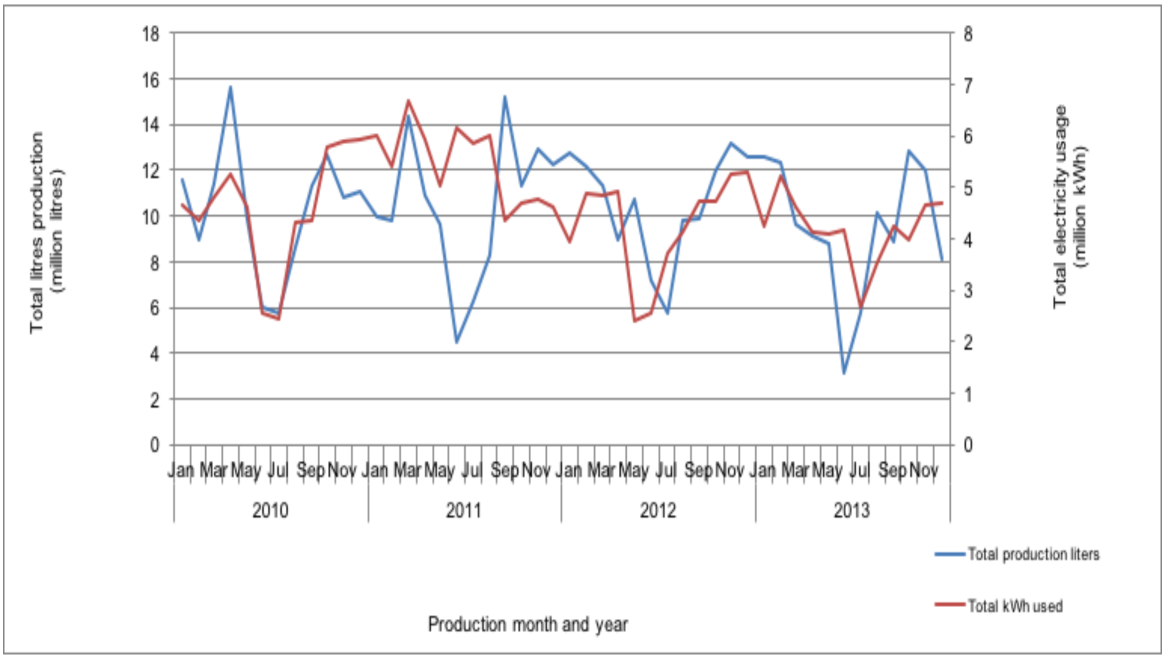


Figure 5.27: Total kWh electricity usage and total litres produced for the four production years (Beverage manufacturing company data)

Another reason for the higher electricity usage is the higher CSD production on sequence E. Production sequence E electricity usage is much higher due to the specific equipment on this production sequence. The lower production volumes but higher electricity usage is possibly due to billing issues from the municipality (Personal communication, engineering manager, August 2014). It does happen that the municipality bill is received late or that no meter readings are taken and an average is calculated by the municipality. It could not be determined how the municipality calculates the average (Personal communication, engineering manager, August 2014). Table 5.12 illustrates the explanation for the higher production volumes for each product type. It is noted that production year 2012 is higher in terms of total production litres and total still production litres produced.

Sequence E produced the highest production volumes in 2011, which can be one of the reasons for the increase in electricity consumption.

Table 5.12: Total production volumes per production year (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Total litres produced	123 520 530	125 459 862	126 144 260	113 313 450
Total CSD litres produced	119 931 839	116 405 044	112 656 727	101 444 609
Total litres still beverages	3 688 330	8 955 510	13 490 910	11 864 260
Total sequence E	61 168 314	68 577 696	65 083 392	56 759 196

Statistical analysis was done to determine if there is any significant difference between the electricity usages in the summer and winter months. The p-value for the difference within summer months is 1.0 and the p-value for the winter months is 0.995. This is an indication that there is no significant difference between the months of electricity usage. The statistical analysis was done to determine if there is any significant difference between years (Appendix K).

The significant difference at 1% confidence level was achieved with a p-value of 0.005. The Tukey HSD test was performed to understand which years differ significantly from each other and the following factors were identified:

- A significant difference at the 5% confidence level between the electricity usage of production years 2011 and 2012
- A significant difference at the 1% confidence level between the electricity usage of production years 2011 and 2013

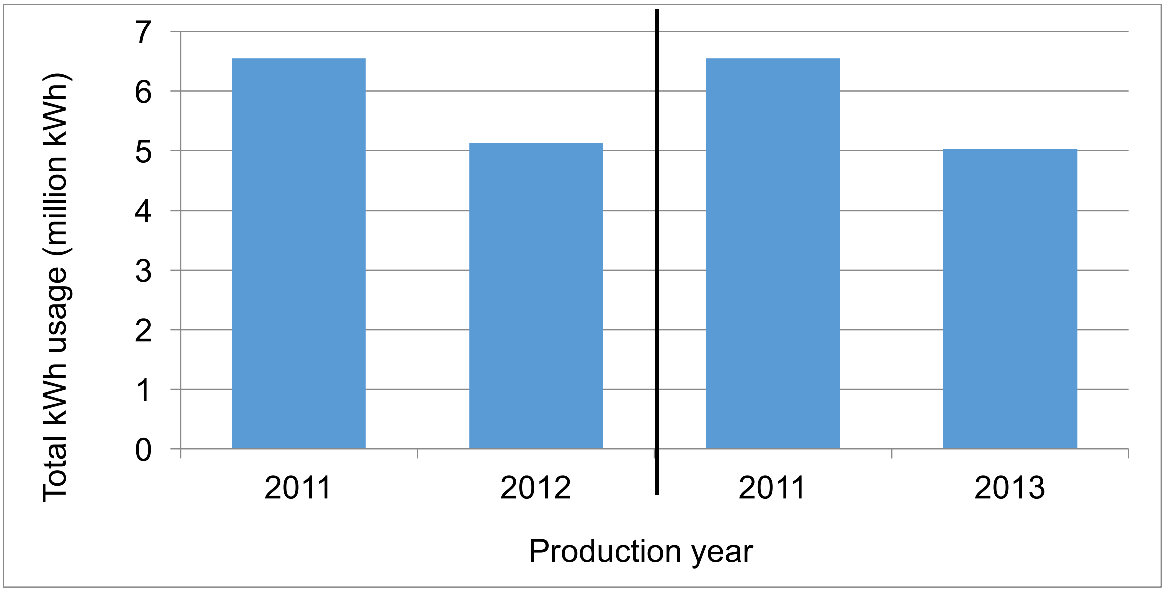


Figure 5.28: Significant difference between production years electricity usage (Beverage manufactuirng company data)

There are various reasons for the electricity difference between the production years. In production year 2012 there was an increase in both the still beverage and the CSD beverage production. Sequence E electricity usage was higher due to the type of equipment on the production line. In production year 2013 the CSD production was the lowest for all four production years. This information can be used by the beverage company to plan ahead regarding an increase in electricity usage when still beverage production and sequence E production increase. It is suggested that if possible the beverage company should rather plan CSD beverage production on sequence A to save electricity.

A study initiated by Exxaro and compiled by Mac Consulting Services in 2013 determine an electricity emission factor for South Africa, found a grid emission factor of 0.940 t CO_2e kWh for the calendar year 2011, which is up to 10% less than the number typically reported and used (NBI, 2013).

Although certain factors are published for a specific application, they vary depending on the needs of the user. Over the years Eskom has published either one or two factors with different definitions; for example for the financial year ended 31 March 2012 factors of 0.99 and 1.03 t CO_2e / kWh were published. In keeping with the GHG Protocol standard, a revised factor for the current Eskom was calculated with adjustments from the calculations published by Eskom. Hence the revised factor is 0.940 t CO_2e / kWh as per Exxaro and Mac Consulting (NBI, 2013).

The information was sourced from the ISO 14001 aspect register and the Scope 2 emissions are used throughout the production process. The Eskom grid emission factors were sourced from yearly online integrated Eskom reports (Eskom, 2015).

Emission type	**Factor**
2010 electricity grid emission factor	0.9800 kWh
2011 electricity grid emission factor	0.9600 kWh
2012 electricity grid emission factor	0.9900 kWh
2013 electricity grid emission factor	1.0300 kWh

The electricity Scope 2 calculations are based on the 60% electricity usage, except for January 2010 to September 2010. Table 5.13 illustrates Scope 2 calculations.

Table 5.13: Scope 2 calculations in kWh for four production years (Beverage manufacturing company data)

Production year	**2010**	**2011**	**2012**	**2013**
Total electricity usage in kWh	5 494 124	6 549 900	5 134 973	5 028 010
Eskom grid emission factor	0.9800	0.9600	0.9900	1.03
Total kWh CO_2e electricity	5 384 242	6 287 904	5 083 623	5 178 850
Total litres produced	123 620 169	125 360 554	126 147 637	113 308 869
Total kg CO_2e per litre unit beverage produced	0.043555	0.050159	0.040299	0.045706
Total g CO_2e per litre unit beverage produced	43.55	50.16	40.30	45.71

The g CO_2e kWh was the highest in production year 2011. This can possibly be because of the boiler change from HFO to natural gas including the additional still beverage production on sequence B and C. It is suggested that the beverage company should consider this information when new changes are made to the beverage plant.

One-way ANOVA was conducted to determine if there is a significant difference between years of electricity usage and production volumes per production year (Appendix L). The statistical analysis indicated that there is no signficant difference between the production years and the electricity usage between production years. So even though a significant difference was identified between electriticy usage and production volumes for some of the years, there is no significant difference within electricity for the four years. This is an indication that if the beverage company does not consider production, the electricity within the company is very stable but as soon as variation in production occurs, it will directly influence the electricity usage.

5.8 PROCESS CARBON FOOTPRINT ANALYSIS

The calculation of carbon footprints requires the use of secondary data in the form of readily available datasets, as well as a variety of emission factors to convert a process such as energy into a CO_2 equivalent emissions values (Brenton *et al.,* 2010). PAS 2050:2011 is prepared by the BSI and co-sponsored by the Carbon Trust and Defra. As previously indicated, Defra emission factors were used for the Scope 1 and Scope 2 calculations.

5.8.1 SCOPE 1 AND SCOPE 2

Scope 1 is calculated by using the emission data for each emission source: CO_2 used in the beverages, LPG gas in forklifts, HFO and natural gas for boiler. Refrigeration gas R22 and ammonia gas were not used in the calculations for Scope 1 emissions. The information presented in Table 5.14 illustrates Scope 1 and Scope 2 CO_2e for each process footprint variable.

Table 5.14 shows that the total CO_2e for the boiler and the electricity is the highest in production year 2011. The direct assumption is made regarding the higher steam and electricity usage for still beverages. Production year 2012 is the highest in total CO_2 usage and this is related to the installation of the new storage tank. Production year 2013 is the highest in LPG, which is directly related to the increase of the warehouse capacity.

Table 5.14: Scope 1 and Scope 2 emission for four production years (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
CO_2 CO_2e kg	2 386 454	3 218 103	3 483 147	3 467 303
LPG CO_2e kg	275	203	328	345
Boiler CO_2e kg	1 034 869	2 942 973	3 331 851	4 413 765
Electricity CO_2e kg	5 384 242	6 287 904	5 083 623	5 178 850
Total footprint CO_2e kg	8 805 480	12 449 184	11 898 950	13 060 264

As shown in Table 5.15, the lowest g CO_2e footprint was achieved in production year 2010 and the highest in production year 2013. The production volume reduction in 2013 is the main reason for the higher g CO_2e / litre footprint. Production year 2011 is the second highest even though production year 2012 produced more volumes than in 2011. The combination of the boiler and electricity increased footprint contributed to the higher footprint in production year 2011.

Table 5.15: Total g CO_2e emission per litre produced (Beverage company data)

Production year	2010	2011	2012	2013
CO_2 g CO_2e / litre	19.90	27.65	30.92	34.18
LPG g CO_2e / litre	0.0022	0.0016	0.0026	0.0030
Boiler g CO_2e / litre	8.37	9.16	6.86	10.06
Electricity g CO_2e / litre	43.55	50.16	40.30	45.71
Total g CO_2e / litre	71.83	86.97	78.08	89.95

The emissions of CO_2 g CO_2e / litre increased each year (as illustrated in Figure 5.29), which is an indication that the beverage company does not manage CO_2 emissions because the CSD volumes decreased each year. The CO_2 usage is related to the amount of CDS products produced, therefore the CO_2 usage is supposed to decrease year on year in relation to the CSD production volumes.

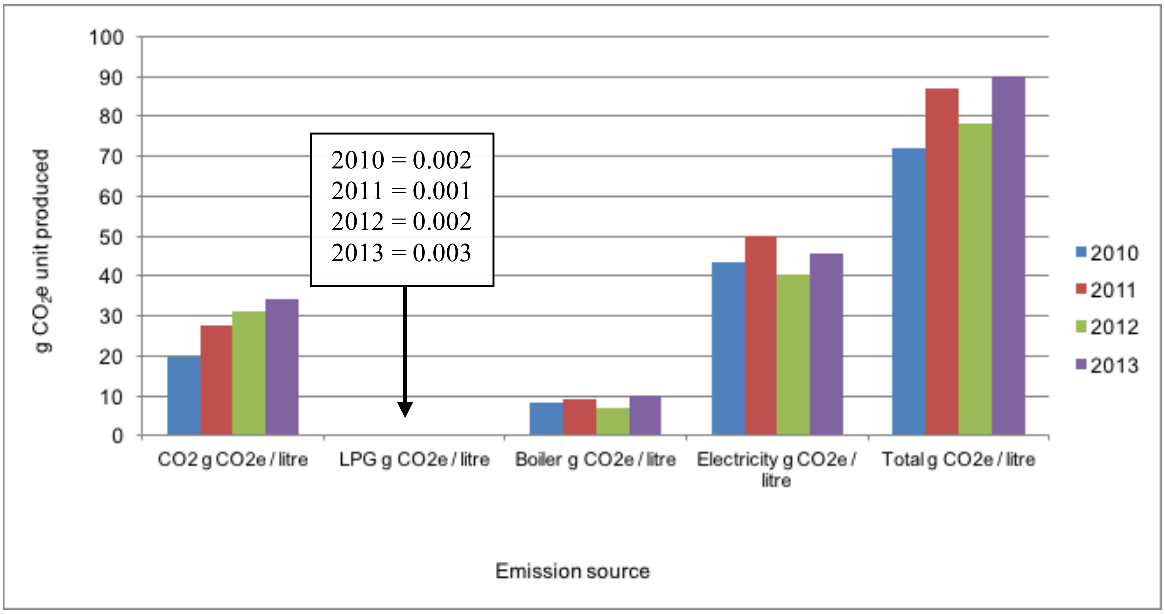


Figure 5.29: Total g CO_2e footprint per emission source and total CO_2e footprint (Beverage manufacturing company data)

LPG consumption increased yearly, except for production year 2011. This can possibly be related to the calculation that was done for production year 2011. The increase of the LPG forklifts is directly related to the increase of the warehouse space as from production year 2012. This indicates that the increase of forklifts will have an effect on total emissions.

Boiler emissions also show an increase, except for production year 2012, considering that not all the data were available for production year 2012. The increase of still beverage production is related to the increase of the boiler emissions.

Electricity usage shows an increase in production year 2011 and then a decrease in 2012. The 2011 increase can be due to the fact that sequence E produced the highest CSD volumes in this year as well as the increase of sequence B production and commissioning of sequence C for still beverages. The fact that production year 2012 was the year with the highest still beverage production it is assumed that the electricity must be the highest for production year 2012. It is possible that the higher level of efficiency caused the production sequence B and C to be achieved in production year 2012. This is an indication that when production lines are producing efficiently, the electricity emissions are lower.

The baseline was set as production year 2010. However The Climate Registry, indicating that if the threshold between the baseline year and the other production years is more than 5% then the baseline year may be re-set to another production year as the new baseline year (The Climate Registry, 2012). It is noted that for the production lines 2011 and 2012 not all the data were available. Production year 2013 was the year with a complete set of data and as well as a number of maintenance works that were scheduled for production year 2013. Table 5.16 illustrates the percentage difference between baseline year 2010 and the other production years.

Table 5.16: Threshold difference between production years (Beverage manufacturing company data)

Production year		**Threshold difference**
2010	**2011**	
9.17 kg CO_2e / litre	10.74 kg CO_2e / litre	15.77% difference
2010	**2012**	
9.17 kg CO_2e / litre	9.77 kg CO_2e / litre	6.33% difference
2010	**2013**	
9.17 kg CO_2e / litre	10.95 kg CO_2e / litre	17.69% difference

Table 5.16 above indicates that there is more than 5% difference between production year 2010 and all the other production years. Based on the fact that production year 2013 is the only year with all the necessary information that is available, the baseline year is re-set to 2013.

5.9 BENCHMARKING FOR A PRODUCT CARBON FOOTPRINT

A key challenge for the packaged food and drinks industry is how to adapt sustainable principles and goals whilst addressing cost, performance and market pressures (Coles & Kirwan, 2011). Benchmarking between the beverage manufacturing company and various other international companies are presented, because the emission factors and variables might differ for the methodologies and calculations used for and in different countries. Furthermore it is not known what emissions were considered when calculating the various Scopes for the specific international or local benchmarking company. The below benchmarking is based on the new baseline year 2013.

Heineken improved their overall energy performance with a reduction from 8.8 kg CO_2e / hl in 2011 to 8.4 kg CO_2e / hl in 2012. This improvement is primarily due to the energy saving activities at their production units, but also due to an increased share of renewable energy (8.0% of total electricity consumption in 2011, compared with 9.3% in 2012), causing the indirect CO_2 emissions to decrease (Heineken, 2012). The Heineken 2013 sustainability report indicates a reduction in CO_2 emissions from 8.4 kg CO_2e / hl in 2012 to 7.7 kg CO_2e / hl in 2013; this is a total of 26% reduction compared to the baseline year 2008 (Heineken, 2013). If the current beverage manufacturing company data are converted to hectolitre and per kg CO_2e then the beverage manufacturing company electricity performance is seen to be lower than Heineken's. The beverage company's performance is reflected in Table 5.17. A reduction is not noted within the beverage company performance as per Heineken's performance since this study was done to indicate the carbon footprint to the beverage company to ensure reduction plans are put in place.

Table 5.17: Electricity performances between Heineken and the beverage manufacturing company (Heineken sustainability reports 2010–2013 and beverage manufacturing company data)

Company and production year	Heineken	Beverage manufacturing company
2010	9.3 kg CO_2e / hl	4.4 kg CO_2e / hl
2011	8.8 kg CO_2e / hl	5.02 kg CO_2e / hl
2012	8.4 kg CO_2e / hl	4.03 kg CO_2e / hl
2013	**7.7 kg CO_2e / hl**	**4.57 kg CO_2e / hl**

In a study conducted in 2008 based on fruit harvesting in South Africa the energy consumption of different pack houses was found to vary between 10 and 20 kWh per ton packed for grape pack houses.

For pome and citrus pack houses the consumption varied between 30 and 45 kWh per ton fruit packed (Blignaut, 2014). The Wine Industry Sustainability 2013 report indicated total emissions of 0.70 kg CO_2e/ litre bottle white wine produced and 0.80

kg CO_2e / litre bottle for red wine produed (Blignaut, 2014). This calculation includes Scope 1, Scope 2 and Scope 3. Considering the fact that Scope 3 was not calculated for the beverage company, the beverage company achieved 0.08kg CO_2e / llitre beverage produced (Table 5.15 - 89.95g CO_2e / litre) in production year 2013. Scope 3 contributed the most to CO_2 emissions, therefore it seems as if the beverage company was achieving better emissions, but it might not be the case since no Scope 3 was calculated for the beverage company.

The Dr Pepper sustainability report of 2014 indicated that their electricity usage in 2011 was 270 million kWh, yielding a rate of 0.17 kWh per gallon of finished product. At the end of 2013 the usage was 254 million kWh at a yielding rate of 0.16 kWh per gallon of finished product (Dr Pepper Snapple Group, 2014). The conversion was done from litres produced at the beverage company to gallons to conduct the benchmarking between Dr Pepper and the beverage company electricity usage.

Table 5.18: Benchmarking between Dr Pepper and the beverage manufacturing company (Dr Pepper Snapple Group, 2014 and Beverage manufacturing company data)

Company and production year	Dr Pepper	Beverage manufacturing company
2011	0.17 kWh / gallon of finished product	0.19 kWh / gallon of finished product
2013	0.16 kWh / gallon of finished product	0.17 kWh / gallon of finished product

A study that was conducted by BIER in 2013 on 18 beverage companies reported the total amount of energy usage in MJ per litre produced. The beer companies used 1.23 MJ / litre produced, the winery companies used 1.67MJ / litre produced and the bottling companies used 0.4 MJ / litre produced. The bottling companies include CSD, juice and bottled water production. Companies specific to CSD production indicated a usage of 0.36 MJ / litre produced (Nelson & Christenson, 2014). The electricity usage was converted from kWh to MJ to benchmark the beverage company electricity usage with the CSD BIER companies (Table 5.19).

Table 5.19: Benchmarking BIER CSD companies against the beverage manufacturing company (Nelson & Christenson, 2014 and beverage manfacturing company data)

Company and production year	BIER CSD companies	Beverage manufacturing company
2013	0.36 MJ / litre product produced	0.16 MJ / litre product produced

It is noted that the beverage manufacturing used less electricity than the CSD company reported by Nelson and Christenson (2014) and that the electricity emission factor and type of energy source had an impact on the electricity usage within the BIER CSD companies.

5.10 WATER FOOTPRINT

5.10.1 INTRODUCTION TO WATER FOOTPRINT

The *Water footprint assessment manual* developed by Hoekstra *et al*. (2011) was used as a guideline for the water footprint calculation in this study. The water uses within the facility is explained in Figure 3.3 and Figure 4.2.

According to Young (2005), most methods of water valuation fit into two broad categories that differ in the basic mathematical procedures:

- Inductive techniques: using a formal statistical or econometric methods
- Deductive techniques: involving logical processes to reason from general premises to particular conclusions

Process water is water that is used as an ingredient in the beverage. Research has shown that process water makes up 70% of a beverage (Dolder, Hillman, Passinsky & Wooster, 2012). This ratio is typically accepted as the standard for measuring water use efficiency within the beverage sector as a whole (BIER, 2011). The food and beverage industries are major consumers of water, with the beverage industry in particular consuming as much as 10–12 tonnes of water per tonne of product produced (Judd & Jefferson, 2003). The majority of water consumed in this industry is used in washing and cleaning operations, which is mainly part of the grey water footprint (Judd & Jefferson, 2003).

In this current study inductive/statistical methods were used to determine the footprint of the manufacturing company and the deductive technique was used to reason the improvement plans for the company. The production plant abstracts water from the local municipality and the waste water is reintroduced into the municipality effluent system as per Figure 3.3. Traditionally water usage in the beverage industry has been quantified on a total volume or normalised volume (volume water used per volume product packaged). Water that comes into the manufacturing facility is used primarily for three different tasks, namely processing, utilities and washing. The processing water is used in the final product and water that is wasted, namely effluent water. Untreated water is used at utilities, for example in the cooling units, boilers, pasteurisers and also result in water to effluent. Washing water, which is both treated and untreated water, is used for CIP, and general cleaning; again resulting in waste water to effluent. Treated water is municipal water that goes through a nano and reverse osmosis treatment system. Untreated water is used directly from the municipality without any treatment.

5.11 PRODUCT WATER FOOTPRINT

5.11.1 WATER VOLUMES

The product water footprint is an indicator of the fresh surface or ground water used within the beverage manufacturing company based on the number of litres produced for each specific production year. Water is received from the local municipality and the water is then treated with a nanotechnology and reverse osmosis water treatment plant. Nanotechnology water treatment systems purify the water by effectively removing contaminants such as heavy metals, and organic and inorganic solutes (Zamxaka, 2010). Reverse osmosis water treatments reduce the levels of total dissolved solids and suspended particles in the water (Dvorak & Skipton, 2014).

The water needs to conform to international customer requirements and this was the basis for the decision to implement the nano and reverse osmosis treatment. The water quality is tested three times, for various parameters, within an eight-hour shift at the beverage manufacturing company laboratory to ensure the water conforms to specification.

The input amount of water against the beverage produced is an indication of the amount of water used per litre of product. The treated water is part of the total amount of water used within the beverage manufacturing company. The treated water used is the amount of water used to produce the final beverage, the water used for the in-line packaging rinsers and the water for the final rinse step in the CIP process. The final rinse water of the CIP process is UV treated water to ensure the water is free from microorganisms. Figure 5.30 indicates the volume of treated and untreated water, in litres, used within the beverage manufacturing company.

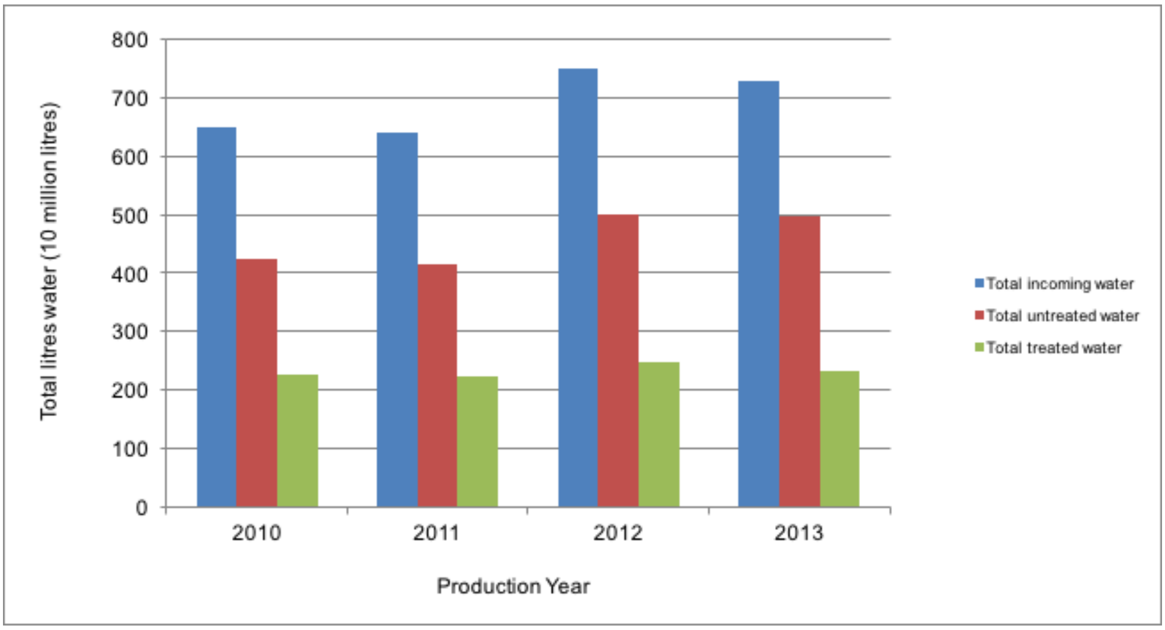


Figure 5.30: Total litres of water used for each production year (Beverage manufacturing company data)

As per Figure 5.30 the “total incoming water” equals the total water that was received from the municipality. The “treated water” is the water that was used in the beverage manufacturing company for the production of the beverages, including water used at the line rinsers and the final CIP rinse water.

The “untreated water” is the water that does not form part of the manufacturing of the product, but still forms part of the total water used within the facility. The untreated water is used for the normal operations such as washing water of floors, ablution water, external cleaning of equipment. The amount of untreated water is calculated by subtracting the total incoming water from the total treated water. Table 5.20 below indicates the amount of total incoming water used within the facility.

Table 5.20: Total water used within the facility in million litres water (Beverage manufacturing company data)

Production year	**2010**	**2011**	**2012**	**2013**
Total incoming water	648.44	639.41	749.53	727.33
Total untreated water	422.94	415.32	500.41	495.70
Total treated water	225.50	224.08	249.12	231.62

It is noted in Table 5.20 that production years 2012 and 2013 are the years with the highest incoming water consumption. Although production year 2013 was the lowest in production volumes of all four production years, production sequence B and sequence C were constant in terms of CSD and still beverage production. It is noted that the still beverage production requires CIP every 20 hours and this contributes to the high water usage. The sand and carbon filters that are part of the nano/reverse osmosis water treatment process must be backwashed (cleaned) every day to ensure the filters are free from any micro-contamination. That means that even if there is no production, the filters must be backwashed and this water goes directly into the effluent drain. Each time the filters are backwashed, 2 400 litres of water are dumped down the effluent drain, amounting to 50 400 litres/month (calculation based on a 21 working day month).

In March 2012 the still beverage production was the highest for all four production years. The municipal water is not just used at the treated water plant but also in the pasteurisation tunnels for sequence B and the flush pasteurisation unit for sequence C. The pasteurising unit on sequence B was always part of the beverage process but sequence C pasteuriser was introduced in September 2011. These two pasteurisers are fed directly from the municipal water sequence and not from the water treatment plant. The pasteurisation unit on sequence C was installed in September 2011 but the unit on sequence B has always been part of the process. The fact that the total still beverage production volumes were higher in March 2012 is a link to the increase of CIP and the water usage from the pasteurisers on sequence B and sequence C.

Figure 5.31 Illustrates the total treated water and the total production litres produced.

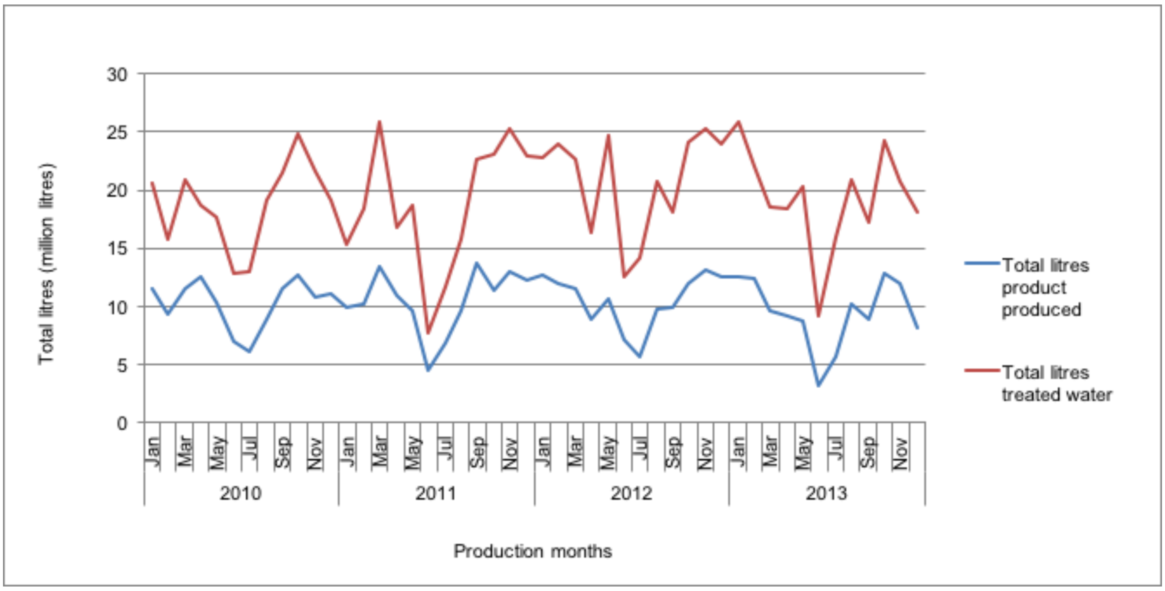


Figure 5.31: Total treated water and total litres product produced for four years (Beverage manufacturing company data)

Figure 5.31 illustrates a similar trend throughout the four-year production regarding the product produced and the total litres of water used within the facility. Once again, it is noted that incoming water was lower in the winter months of each production year, which is also the time when most of the maintenance was scheduled.

Table 5.21: Total treated water and total production per month and year in million litres (Beverage manufacturing company data)

Year	2010		2011		2012		2013	
	Total treated water	Prod volumes	Total treated water	Prod volumes	Total treated water	Prod volumes	Total treated water	Prod volumes
Jan	20.55	11.56	15.39	9.99	22.82	12.74	25.79	12.56
Feb	15.82	9.32	18.40	10.19	23.89	11.99	22.07	12.35
Mar	20.81	11.56	25.84	13.38	22.60	11.49	18.57	9.65
Apr	18.67	12.56	16.75	10.91	16.28	8.93	18.42	9.15
May	17.68	10.42	18.67	9.64	24.67	10.71	20.25	8.78
Jun	12.84	7.02	7.72	4.58	12.61	7.18	9.22	3.15
Jul	12.96	6.05	11.61	6.82	14.13	5.75	15.94	5.73
Aug	19.08	8.94	15.74	9.62	20.75	9.79	20.95	10.16
Sep	21.41	11.55	22.57	13.68	18.14	9.87	17.22	8.84
Oct	24.89	12.66	23.12	11.40	24.10	11.96	24.26	12.83
Nov	21.65	10.85	25.29	12.92	25.25	13.17	20.80	12.02
Dec	19.13	11.13	22.98	12.24	23.89	12.55	18.12	8.10
Total	225.5	123.62	224.08	125.36	249.12	126.15	231.62	113.31

Water meters are in place to measure the total amount of incoming water and the total treated water used in the facility but no meters are in place to determine the total untreated water used. Figure 5.32 illustrates the difference between the treated and untreated water used in the facility.

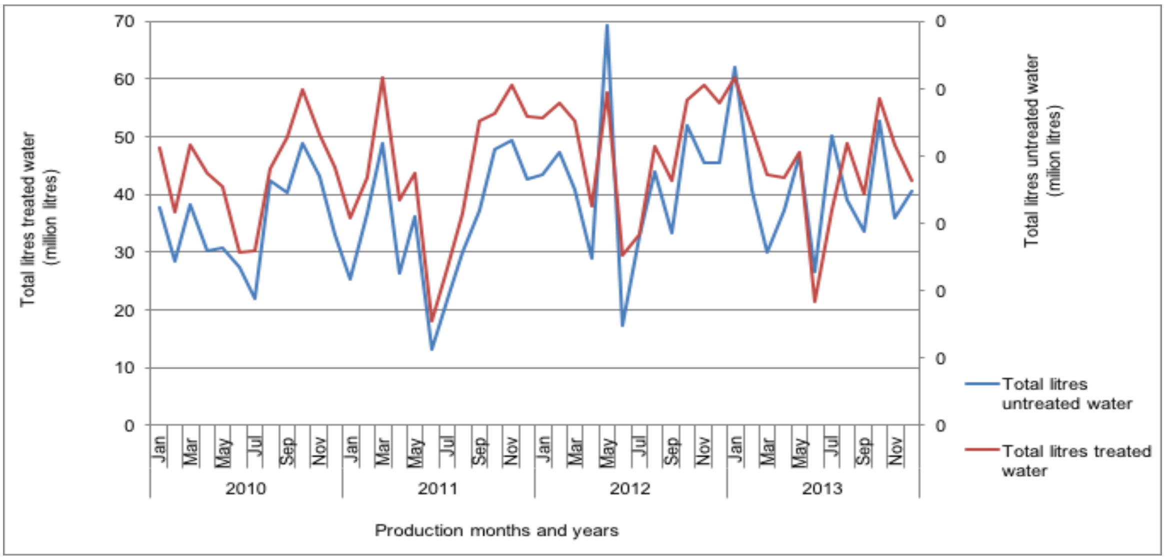


Figure 5.32: Total treated water and total untreated water used (Beverage manufacturing company data)

According to Figure 5.32 it seems as if the water trending is similar but a statistical analysis was done to understand if there is a significant difference between the treated water and untreated water for all four production years. A spike is noted in the treated and untreated water in the month of May 2012; this is due to work that was done on the production floors in production year 2012. The untreated water was used to prepare the floors and was used throughout the reconstruction of the floors.

Table 5.22 indicates the total million litres of treated and untreated water used in the facility.

Table 5.22: Treated and untreated water in million litres (Beverage manufacturing company data)

Year	2010		2011		2012		2013	
	Treated water	Untreated water	Treated water	Untreated water	Treated water	Untreated water	Treated water	Untreated water
Jan	20.55	37.78	15.39	25.42	22.82	43.40	25.79	61.92
Feb	15.82	28.36	18.40	36.66	23.89	47.20	22.07	40.82
Mar	20.81	38.30	25.84	48.76	22.60	40.75	18.57	30.06
Apr	18.67	30.17	16.75	26.33	16.28	28.97	18.42	37.11
May	17.68	30.88	18.67	36.18	24.67	69.37	20.25	46.89
Jun	12.84	27.40	7.72	13.30	12.61	17.42	9.22	26.73
Jul	12.96	22.04	11.61	21.62	14.13	32.86	15.94	50.26
Aug	19.08	42.30	15.74	29.98	20.75	43.97	20.95	39.12
Sep	21.41	40.41	22.57	37.22	18.14	33.33	17.22	33.57
Oct	24.89	48.94	23.12	47.73	24.10	52.05	24.26	52.73
Nov	21.65	43.19	25.29	49.49	25.25	45.61	20.80	35.99
Dec	19.13	33.16	22.98	42.65	23.89	45.46	18.12	40.51
Total	225.50	422.94	224.08	415.32	249.12	500.41	231.62	495.70

One-way ANOVA (Appendix M) was done in an attempt to determine whether there is a significant difference and it is noted that no significant difference existed at the 5% confidence level on both the treated and untreated water between the production years (p=0.096). A significant difference of 1% confidence level was identified for both treated and untreated water between production months (p=0.006). The fact that there is a significant difference between months is an indication that the production volumes differed as per the water usage. Figure 5.33 illustrates the total litres for all four production years combined for treated and untreated water.

As shown in Figure 5.33, the beverage company can plan around the lower and higher production months in terms of environmental control and financial planning. The trend lines on both graphs show a similar trend, which is an indication of the difference between months. An increase in water usage is also noted during the summer months.

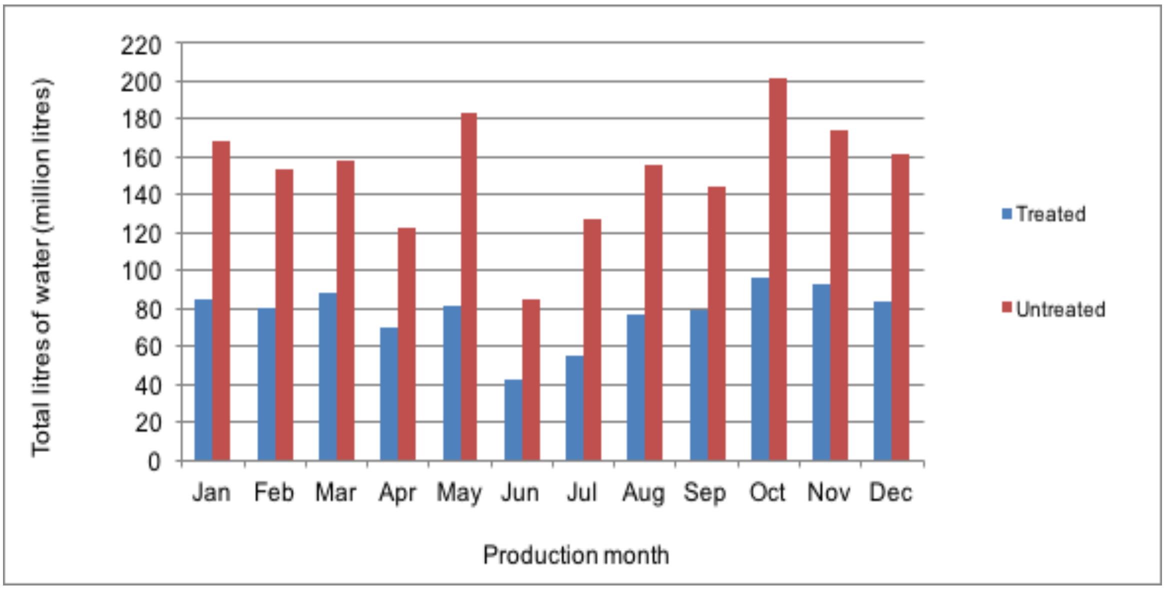


Figure 5.33: Significant difference between treated and untreated water for combined production months of all four production years (Beverage manufacturing company data)

There are no meters for the untreated water therefore it is not possible to determine which services within the production facility used most of the untreated water. It was also noted in the total litres of still beverage production that sequence B and sequence C make use of pasteurisers due to the nature of the product. Production sequence B pasteuriser tunnel uses 10 000 litres of untreated water to be filled up and production sequence C uses about 2 000 litres. Both the pasteurisers lose water through steam evaporation when the units are in operation. The untreated water increased in 2012. This increase reflects the higher still beverage production in this production year, which was 13 490 910 litres still beverage product in total in comparison with the other years: 2010 just over 3.6 million litres, 2011 just under 8.9 million and 2013 just over 11.8 million litres.

Figure 5.34 illustrates the amount of untreated water used in the beverage company and the total amount of product produced in the four years. There are water meters on the treated water sequence to ensure the beverage company has quantitative volume control over the amount of water used for production. The treated water used in June 2011 indicates a drop in usage and this is due to the packaging changes within the production facility during this time.

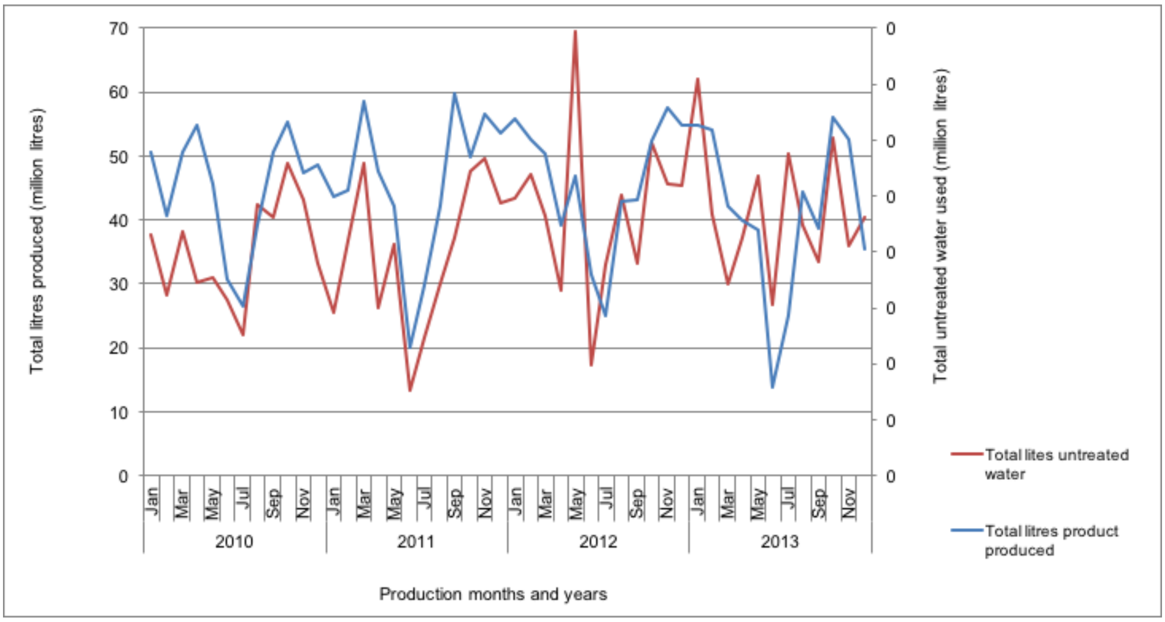


Figure 5.34: Untreated water usage for all four production years (Beverage manufacturing company data)

The drop noted in June 2013 is also directly related to the packaging changes that were planned in the production plant. The litres of treated water used during the production for the total beverage production follow a similar trend each year, which is an indication that the blue water footprint per year might not differ much between each production year. One-way ANOVA analysis (Appendix N) was conducted to determine whether there is a significant difference between treated water usage over each production year and per production months. It can be concluded from the analysis that there is no significant difference at the 5% confidence level between years ($p = 0.219$) and there is a significant difference at the 1% confidence level between months ($p = 0.0034$). The trend for treated water usage within years are similar but not within production months. This trend is similar to that of the untreated water.

Two-way ANOVA (Appendix O) was conducted in an attempt to determine whether the treated water consumption is also seasonally driven as per the production volumes discussed in Figure 5.35. The conclusion can be made that there is no significant difference between the water usage per production years on the 5% confidence level ($p = 0.510$) but there is a significant difference at the 1% level between the winter and summer seasons ($p < 0.001$).

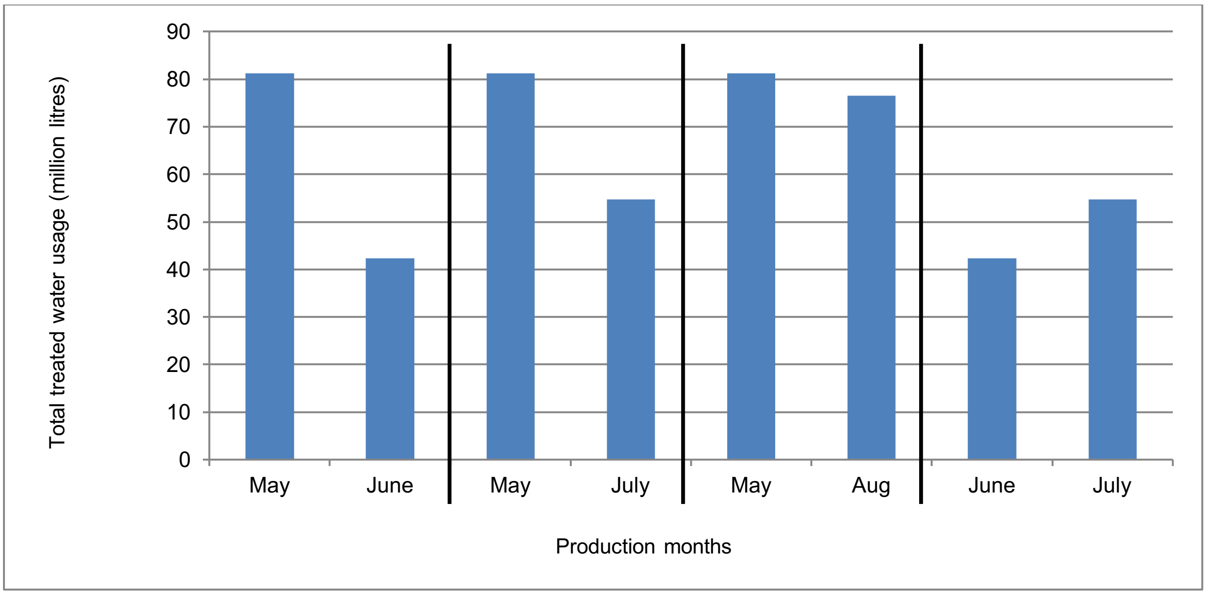


Figure 5.35: Significant differences between winter months of all four production years illustrated by aid of a bar chart (Beverage manufacturing company data)

This was also seen for the seasonal demand within the total production volumes. It is evident, therefore, that water usage and production volumes are related. Thus, the beverage company can plan higher water usage during higher production months.

In the latter part of 2011 (September) the still beverage production was introduced onto sequence C and this is reflected on the increased water usages from September 2011. The still beverage is very sensitive to microorganisms; therefore, CIP needs to be conducted every 20 hours, which is a possible reason for the increase in treated water usage as from September 2011. June 2013 shows a reduction in treated water usage and this was mainly due to the maintenance that was scheduled on most of the production sequences based on the new packaging neck design change.

5.11.2 BLUE WATER FOOTPRINT

The input amount of water against the volume of beverage produced is an indication of the amount of water used per litre of product. The blue water footprint for the manufacturing company is calculated by considering the total incoming water and the total litres of production. Even though not all the incoming water is imbedded in the final product, the water is used by the facility within the processes.

The treated water used is the amount of water used to produce the final beverage including the water used in the on-line rinsers and final rinse of CIP process. The rest of the water used within the facility is untreated water.

The process water footprint is calculated as follows for each production year:

2010 WF_{proc} = Total incoming water in litres / total production volumes in litres
= 648 440 550.60 litres / 123 620 169.58 litres
= 5.25 litres per unit of product produced

This is an indication that for production year 2010 the manufacturing company used 5.25 litres of water to produce one litre of final beverage product.

2011 WF_{proc} = Total incoming water in litres / total production volumes in litres
= 639 409 647.97 litres / 125 360 554.84 litres
= 5.10 litres per unit of product produced

This is an indication that for production year 2011 the manufacturing company used 5.10 litres of water to produce one litre of final beverage product.

2012 WF_{proc} = Total incoming water in litres / total production volumes in litres
= 749 533 038.43 litres / 126 147 637.00 litres
= 5.94 litres per unit of product produced

This is an indication that for production year 2012 the manufacturing company used 5.94 litres of water to produce one litre of final beverage product.

2013 WF_{proc} = Total incoming water in litres / total production volumes in litres
= 727 325 120.02 litres / 113 308 869.44 litres
= 6.42 litres per unit of product produced

This is an indication that for production year 2013 the manufacturing company used 6.42 litres.

Figure 5.36 illustrates the total amount of water used against the total litres of product produced with the blue water footprint.

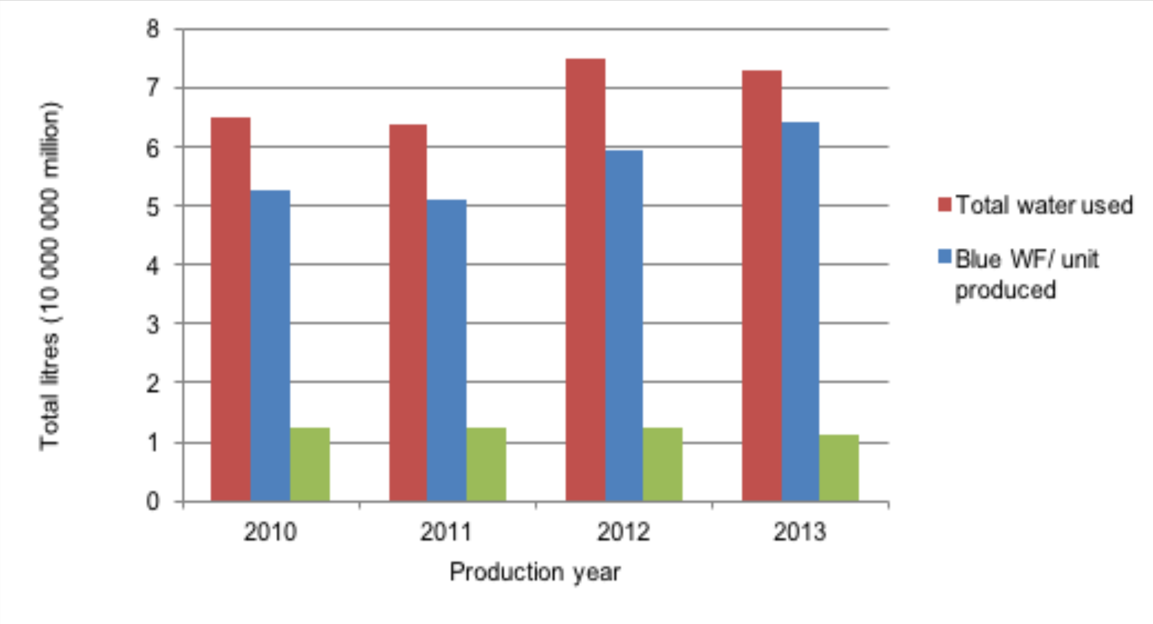


Figure 5.36: Water footprint per unit of product produced, total litres water used and total product produced in 10 000 000 million litres (Beverage manufacturing company data)

The blue water footprint and the total water used within the process follow a similar trend regarding the increase from production year 2010 to production year 2013 are illustrated in Figure 5.36. A decrease is noted for the total product produced from 2010–2013. This is an indication that the beverage manufacturing company used unnecessary water within the process because the production volumes decreased and the total litres of water increased.

5.11.3 GREY WATER FOOTPRINT

For the purpose of this study, the grey water footprint is defined as the amount of water that is transferred to the effluent drain divided by the total litres of product produced:

$$\text{Grey water footprint} = \frac{\textit{Total effluent litres within all processes}}{\textit{Total litres of product produced}}$$

The pollutant load in the effluent is also calculated to indicate to the beverage company what the level of pollutant load is in the effluent water and to determine the pollutant load water footprint. The grey water figures were sourced from the effluent accounts received monthly from the local municipality.

2010 Grey water footprint = $\frac{\text{4 246 830 effluent litres}}{\text{123 520 530 production litres}}$

= 0.03 litres effluent per unit product produced

2011 Grey water footprint = $\frac{\text{5 984 090 effluent litres}}{\text{125 459 865 production litres}}$

= 0.05 litres effluent per unit product produced

2012 Grey water footprint = $\frac{\text{10 737 070 effluent litres}}{\text{126 144 260 production litres}}$

= 0.09 litres effluent per unit product produced

2013 Grey water footprint = $\frac{\text{20 351 190 effluent litres}}{\text{113 313 450 production litres}}$

= 0.18 litre effluent per unit product produced

Table 5.23: Grey water footprint with effluent and production litres produced (Beverage manufacturing company data)

Production year	**2010**	**2011**	**2012**	**2013**
Total effluent litres	4 246 830	5 984 090	10 737 070	20 351 190
Total production litres	123 520 530	125 459 865	126 144 260	113 313450
Grey water footprint (l/l)	0.03	0.05	0.09	0.18

It is noted that the total effluent litres and grey water footprint increased in each production year and the total litres produced decreased as from production year 2011. It is suggested that the beverage manufacturing company should consider this information for the future to ensure that once production volumes are lower, that effluent water is also reduced. The beverage company should prevent unnecessary water wastage during lower production months and production years. Figure 5.37 illustrates the grey water footprints for all four production years.

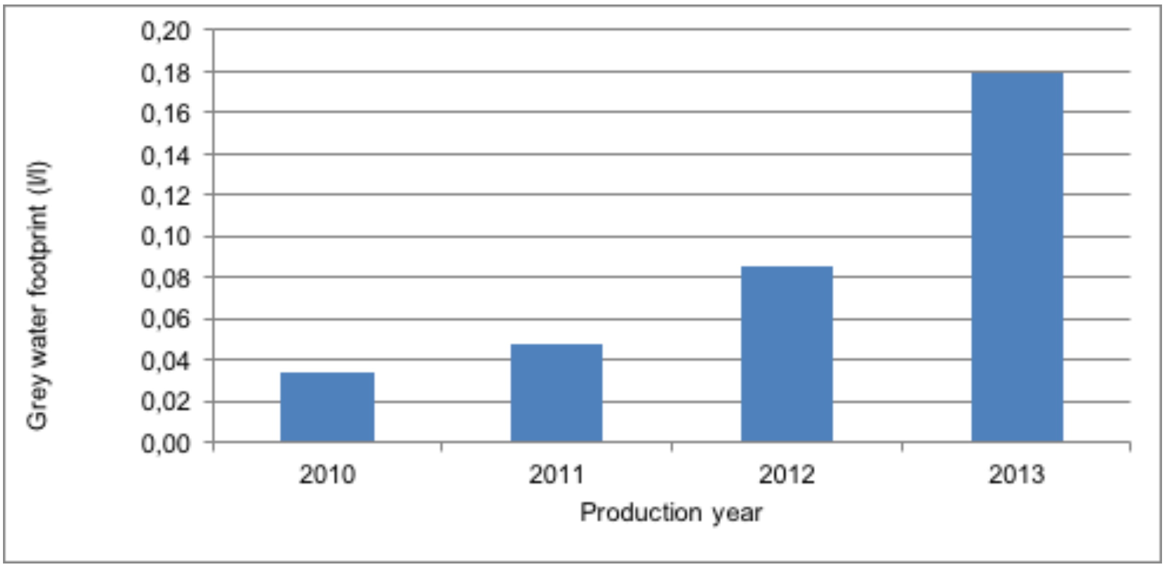


Figure 5.37: Grey water footprints (l/l) for the four production years (Beverage manufacturing company data)

The grey water increased dramatically in production year 2013. No substantial changes occurred within the beverage company that could contribute to the higher grey water footprint in 2013. Two-way ANOVA (Appendix P) was done to determine the significant difference between the effluent water and no significant difference was noted between months but a significant difference at the 5% confidence level was noted between production years (p = 0.022). Production year 2013 was identified as the most significantly different from the other production years (similar to Figure 5.37).

5.11.4 GREY POLLUTANT LOAD WATER FOOTPRINT

As per the water footprint assessment manual (Hoekstra, *et al.* 2011) the grey water footprint is calculated by identifying the pollutant load in the water, the maximum acceptable concentration of the specific pollutant and the natural concentration of this specific pollutant. The natural concentration is to get water quality as if it was in the original receiving area, example a dam or river.

$WF_{proc.grey} = L / (C_{max} – C_{nat})$

L = pollutant load

C_{max} = the maximum acceptable concentration in mass/volume

C_{nat} = the natural concentration in the receiving water body in mass/volume

For each pollutant the total of the year was used as the pollutant load (L) value. Monthly data were calculated, compared and verified by the yearly data and the same results were obtained; therefore the year total are presented here.

The municipal charges are based on the breaching specification parameters determined from the test results as conducted by the municipality testing laboratory. The local municipality uses the Ekurhuleni Metropolitan Schedule 4 (Table 5.24) as a guideline regarding testing parameters maximum allowance (Ekurhuleni Metropolitan Municipality, 2013). The beverage laboratory verifies some of the tests in-house and other tests are verified by making use of an external testing laboratory. The reason for the verification process is to ensure that the local municipality does not overcharge the beverage manufacturing company.

Table 5.24 Municipal charges (Schedule 4).

Pollutant load	Maximum allowance
Chemical Oxygen Demand (COD)	5000 mg / litre
Phosphates (P)	50 mg / litre
Nitrates (N)	200 mg / litre
Suspended Solids (SS)	500 mg / litre

The local municipality samples effluent water on a weekly basis from a sample point, which is situated on the beverage manufacturing site. The municipality performs various tests on the effluent water to understand the pollutant load of the effluent water. It does sometimes happen that the municipality bill is not issued on time and the out of specification results are not directly related to the specific billing month (Personal communication, service manager, manufacturing site, September 2014). The municipality used the sample effluent water on a weekly basis but since 2013, the municipality only sampled twice a month. Thus from 2013 the average sets of samples are less than the other production years (2010–2012) influencing the results because of fewer samples were taken to calculate the pollutant load (Personal communication, service manager, manufacturing site, September 2014).

Each pollutant load is discussed in more detail to give an idea regarding the load that was measured for each production year. The local municipality had specifications for each pollutant load and if the result of the beverage manufacturing company effluent was above the specification, a penalty was added to the monthly bill. This information was used to calculate the C_{max} of the effluent water.

The South African National Standard (SANS) 241 Drinking Water Specification is a definitive reference on acceptable limits for drinking water quality parameters in South Africa and provides limits for a range of water quality characteristics. The SANS 241:2011 Drinking Water Specification effectively summarises the suitability of water for drinking water purposes by specifying a single class of water which is acceptable for lifetime consumption (Bila-Mupariwa, 2008).

The policy of the DWA requires the maximum utilisation of scarce water resources, and that all effluent is treated and returned to its natural water courses. Water quality guidelines for aquatic ecosystems provides information that can be used to determine the degree to which water quality may be altered through the return of effluent without compromising the health of the aquatic ecosystem (Holmes, 1996). These water guidelines are not clear on all the C_{nat} variables for each calculation parameter that was needed for this study. The World Health Organization's water guidelines, Class IV – freshwater quality for the maintenance of aquatic life, were therefore used for all the C_{nat} calculations as indicated in Table 5.25 (Enderlein, Enderlein & Williams, 1997).

Table 5.25 Class IV guidelines (Enderlein *et al.,* 1997)

Parameter	**C*nat***
Chemical Oxygen Demand	30 mg / l
Phosphates	0.13 mg / l
Nitrates	0.25 mg / l
Suspended Solids	100 mg / l

5.11.4.1 CHEMICAL OXYGEN DEMAND

Figure 5.38 illustrates the chemical oxygen demand (COD) in the effluent water of the manufacturing company. The COD is a parameter used to determine the amounts of organic pollutant in water (Yau, Wang & Zhou, 2014). The COD is defined as the number of oxygen equivalents consumed in the oxidation of organic compounds by strong oxidising agents and is indicative of the amount of organic pollutants present in a test sample (Yau *et al.*, 2014). The COD in the manufacturing company effluent is directly related to the amount of sugar in the effluent (Personal communication, service manager, manufacturing site, September 2014). Sugar is present in effluent because each time the company produces a new product flavour product is dumped down the drain during the start-up process. The first product is dumped to ensure that the correct quality of product is transferred to the filler for production; this product is directly dumped into the effluent system. There are various other processes that also contribute to product being dumped down the drain, thus increasing the COD levels in the effluent. Some of these processes occur during the filling process when product is spilled at the filler, or during the reworking of quarantine product back into the process and the first step within the CIP step is also dumped down the drain.

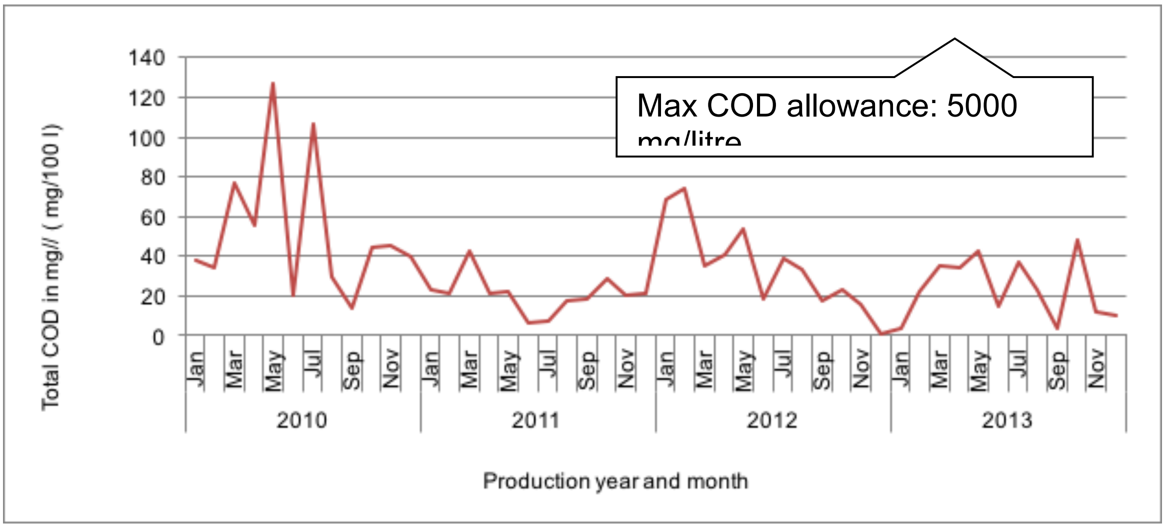


Figure 5.38: Total chemical oxygen demand for each production year (Beverage manufacturing company data)

Higher COD levels are noted in the effluent during May and July 2010 and the rest of the production months have a very similar trend. The reason for the higher levels in 2010 is related to the introduction of a new sugar dissolving system in the manufacturing facility. During the commissioning phase high quantities of concentrated produce were discharged into the effluent system due to technicalities at the new sugar dissolving system (Personnel interview, service manager, manufacturing company, September 2014). The local municipality maximum specification for COD is set at 5 000 mg/l (Ekurhuleni Metropolitan Municipality, 2013).

Table 5.26: Total chemical oxygen demand in mg / litre for each production year (Beverage manufacturing company data)

Production year	**2010**	**2011**	**2012**	**2013**
Jan	3 800	2 280	6 820	361
Feb	3 391	2 126	7 400	2 240
Mar	7 670	4 210	3 495	3 515
Apr	5 570	2 150	4 095	3 445
May	12 664	2 245	5 363	4 225
Jun	2 035	687	1 830	1 451
Jul	10 613	710	3 890	3 706
Aug	2 985	1 782	3 350	2 271
Sep	1 372	1 825	1 785	375
Oct	4 442	2 895	2 266	4 850
Nov	4 520	2 072	1 552	1 198
Dec	4 000	2 094	102	1 044
Average	5255	2090	3496	2390
Total	63 062 mg / l	25 075 mg / l	41 948 mg / l	28 681 mg / l

Two-way ANOVA was conducted to determine whether there is a significant difference between the COD levels and four production years (Appendix Q). The conclusion is that there is a significant difference at the 0.1% confidence level ($p = 0.001$) between years and also a significant difference at the 5% confidence level between months ($p = 0.033$). The Tukey HSD tests were performed to understand the difference within the data, which indicate that there is a significance 1% confidence level difference between production years 2010 and 2011 and a significance 5% confidence level difference between production year 2010 and 2013.

2010 COD $WF_{proc.grey}$ = L / (C_{max} – C_{nat})

= 63 062.00 mg / litre / (5 000 mg / litre – 30 mg / litre)

= 12.69 mg / litre COD for production year 2010

2011 COD $WF_{proc.grey}$ = L / (C_{max} – C_{nat})

= 25 075.60 mg / litre / (5 000 mg / litre – 30 mg / litre)

= 5.05 mg / litre COD for production year 2011

2012 COD $WF_{proc.grey}$ = L / (C_{max} – C_{nat})

= 41 948.00 mg / litre / (5 000 mg / litre – 30 mg / litre)

= 8.44 mg / litre COD for production year 2012

2013 COD $WF_{proc.grey}$ = L / (C_{max} – C_{nat})

= 28 681.00 mg / litre / (5 000 mg / litre – 30 mg / litre)

= 5.77 mg / litre COD for production year 2013

5.11.4.2 PHOSPHATES

Figure 5.39 indicates the amount of total phosphates in the effluent water. The DWA measures ortho-phosphate as phosphorous in the effluent water (DWA, 2013). Phosphate compounds are found in waste water as a result of fertilisers washed out of the soil, human and animal excretions, detergents and chemical agents (DWA, 2013). The manufacturing company introduces phosphates to the effluent due to the chemicals used in the production process and the following services: water treatment, boiler, cooling units and general cleaning in the production facility (Personal communication, service manager, manufacturing company, September 2014).

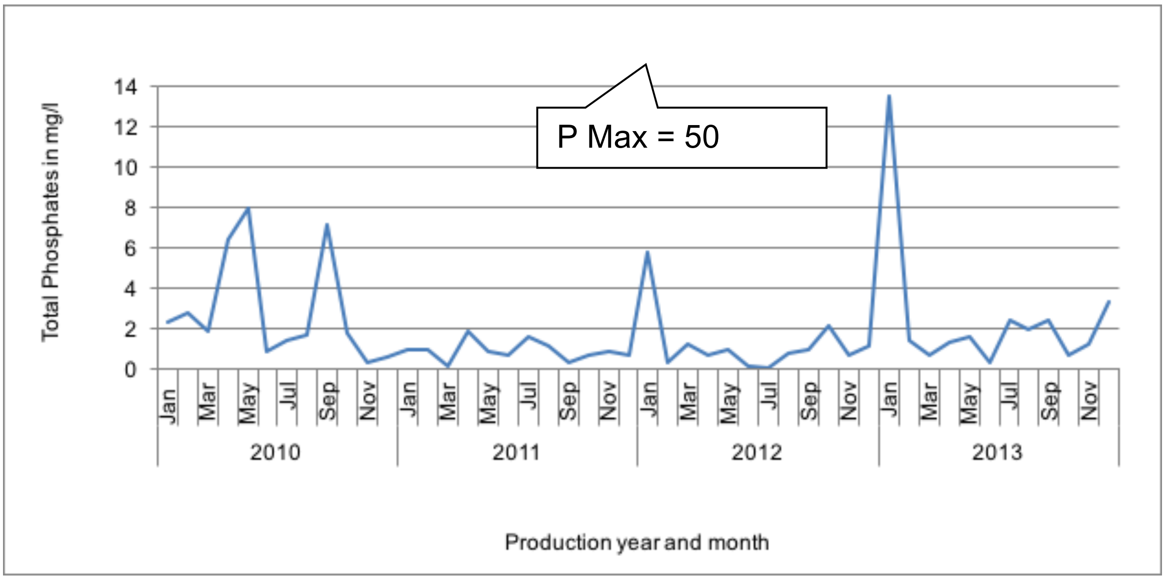


Figure 5.39: Total phosphates for each production year (Beverage manufacturing company data)

The maximum specification for phosphates in effluent water is 50 mg / litre (DWA, 2013). The total production in December 2012 was much higher than other production months and this contributed to the higher phosphate levels that were measured in January 2013. In general the manufacturing company phosphates levels are much lower than the maximum allowance from the local municipality, which is 50 mg / litre (Ekurhuleni Metropolitan Municipality, 2013).

Table 5.27: Total phosphates in mg / litre for each production year (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Jan	2.33	0.94	5.80	13.50
Feb	2.77	0.97	0.25	1.40
Mar	1.80	0.10	1.22	0.65
Apr	6.40	1.80	0.69	1.32
May	8.00	0.80	0.95	1.55
Jun	0.80	0.63	0.15	0.25
Jul	1.37	1.55	0.05	2.40
Aug	1.63	1.10	0.73	1.95
Sep	7.15	0.33	0.95	2.35
Oct	1.75	0.65	2.10	0.65
Nov	0.30	0.86	0.65	1.20
Dec	0.60	0.65	1.10	3.30
Average	2,91	0,87	1,22	2,54
Total	34.90 mg / l	10.38 mg / l	14.64 mg / l	30.52 mg / l

Two-way ANOVA (Appendix R) was conducted to determine whether there is a significant difference between each production year in terms of phosphate results. The conclusion is that there is no significant difference at the 5% confidence level between years ($p = 0.082$) and also no significant difference at the 5% confidence level between months ($p = 0.136$).

2010 Phosphates $\boldsymbol{WF_{proc.grey}} = L / (C_{max} - C_{nat})$

$= 34.90$ mg / litre / (50 mg / litre – 0.13 mg / litre)

$= 0.70$ mg / litre phosphates for production year 2010

2011 Phosphates $\boldsymbol{WF_{proc.grey}} = L / (C_{max} - C_{nat})$

$= 10.38$ mg / litre / (50 mg / litre – 0.13 mg / litre)

$= 0.21$ mg / litre phosphates for production year 2011

2012 Phosphates $\boldsymbol{WF_{proc.grey}} = L / (C_{max} - C_{nat})$

$= 14.64$ mg / litre / (50 mg / litre – 0.13 mg / litre)

$= 0.29$ mg / litre phosphates for production year 2012

2013 Phosphates $\boldsymbol{WF_{proc.grey}} = L / (C_{max} - C_{nat})$

$= 30.52$ mg / litre / (50 mg / litre – 0.13 mg / litre)

$= 0.61$ mg / litre phosphates for production year 2013

5.11.4.3 NITRATES

The total amount of nitrates per production year is indicated in Figure 5.40. Nitrates are measured as nitrogen as per the DWA (2013). Nitrogen is one of the main biogeochemical elements and the most important reactions involving nitrogen are driven by either microorganisms or enzymes (Tredoux, Engelbrecht & Israel, 2009).

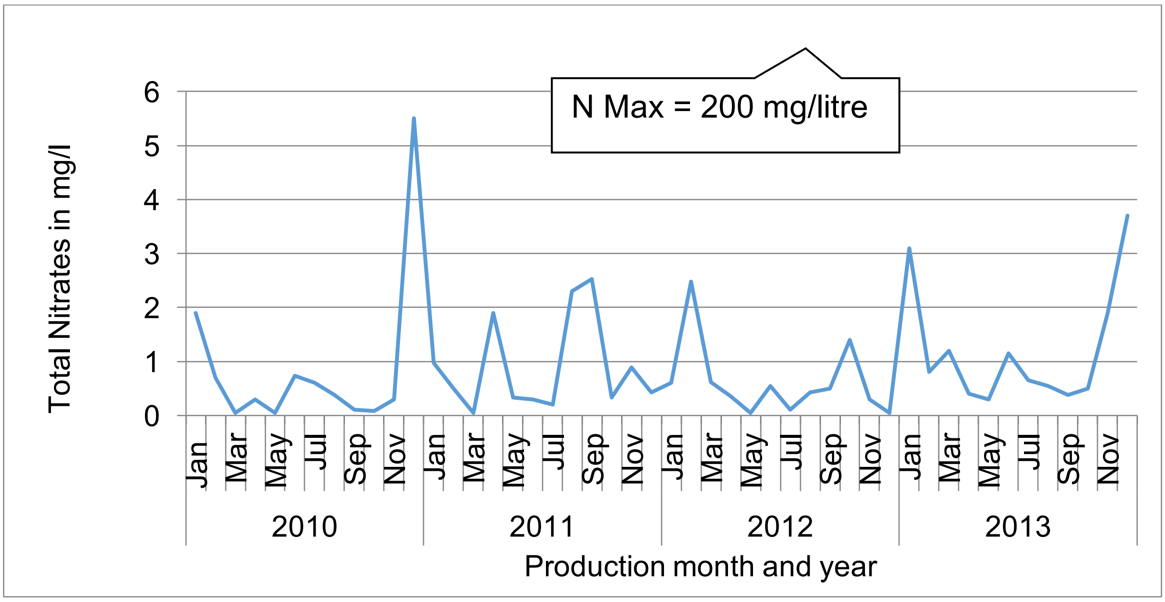


Figure 5.40: Total nitrates for each production year (Beverage manufacturing company data)

The maximum specification of the local municipality for the amount of nitrates in the effluent water is maximum 200 mg / litre (Ekurhuleni Metropolitan Municipality, 2013). The results achieved by the manufacturing company are much lower than the maximum allowed by the municipality. This is an indication that the manufacturing company is managing the microbial load in the effluent water.

Table 5.28: Total nitrates in mg / litre for each production year (Beverage manufacturing company data)

Production year	**2010**	**2011**	**2012**	**2013**
Jan	1.90	0.98	0.60	3.10
Feb	0.70	0.50	2.48	0.80
Mar	0.05	0.05	0.62	1.20
Apr	0.30	1.90	0.35	0.40
May	0.05	0.33	0.05	0.30
Jun	0.73	0.30	0.55	1.15
Jul	0.60	0.20	0.10	0.65
Aug	0.38	2.30	0.43	0.55
Sep	0.10	2.53	0.50	0.38
Oct	0.08	0.33	1.40	0.50
Nov	0.30	0.89	0.30	1.90
Dec	5.50	0.43	0.05	3.70
Average	0,89	0,89	0,62	1,22
Total	10.69 mg / l	10.73 mg/ / l	7.43 mg / l	14.63 mg / l

Two-way ANOVA (Appendix S) was conducted to determine whether there is a significant difference between each production year in terms of nitrate results. The conclusion is that there is no significant difference at the 5% confidence level between years ($p = 0.594$) and no significant difference at the 5% confidence level between months ($p = 0.264$).

2010 Nitrates $\boldsymbol{WF_{proc.grey}}$ $= L / (C_{max} – C_{nat})$
$= 10.69$ mg / litre / (200 mg / litre – 0.25 mg / litre)
$= 0.05$ mg / litre Nitrates for production year 2010

2011 Nitrates $\boldsymbol{WF_{proc.grey}}$ $= L / (C_{max} – C_{nat})$
$= 10.73$ mg / litre / (200 mg / litre – 2.5 mg / litre)
$= 0.05$ mg / litre Nitrates for production year 2011

2012 Nitrates $\boldsymbol{WF_{proc.grey}}$ $= L / (C_{max} – C_{nat})$
$= 7.43$ mg / litre / (200 mg / litre – 2.5 mg / litre)
$= 0.04$ mg / litre Nitrates for production year 2012

2013 Nitrates $\boldsymbol{WF_{proc.grey}}$ $= L / (C_{max} – C_{nat})$
$= 14.63$ mg / litre / (200 mg / litre – 2.5 mg / litre)
$= 0.07$ mg / litre Nitrates for production year 2013

5.11.4.4 SUSPENDED SOLIDS

The suspended solids in effluent water are due to any material that cannot be filtered out of the water or that cannot dissolve in the effluent water. Suspended solids include biological or organic carbon or formation of corrosion products and/or ingredients of solids (DWA, 1996). Figure 5.41 illustrates the amount of suspended solids in the manufacturing company effluent water. The maximum specification for the local municipality for suspended solids is 500 mg / litre.

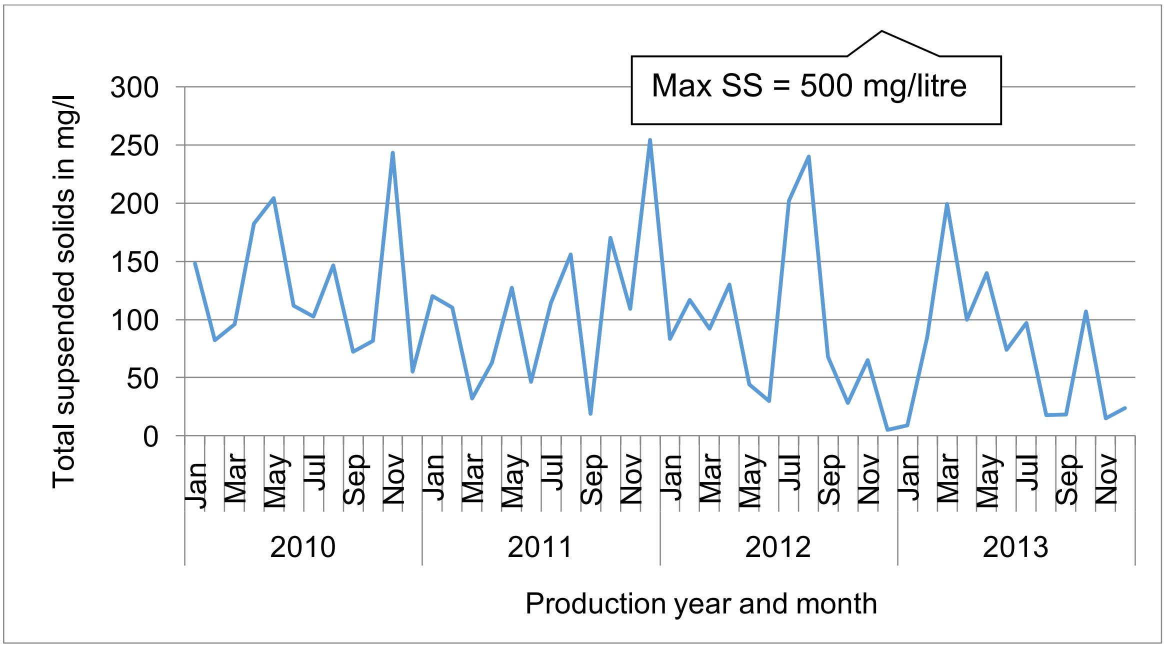


Figure 5.41: Total suspended solids for each production year (Beverage manufacturing company data)

The amount of suspended solids in the effluent water is lower than the municipality maximum specification of 500 mg / litre (Ekurhuleni Metropolitan Municipality, 2013). There is no trend in the suspended solids when compared to the other effluent parameter results and it is difficult to identify the main reason for the erratic results. A possible reason – but not the only one – is that the manufacturing company carried out scheduled construction work on the floors in production year 2011, which contributed to the higher suspended solids results. Another possible reason is the daily backwashing of the carbon filters.

Table 5.29 illustrates the total suspended solids against each production year.

Table 5.29: Total suspended solids in mg / litre for each production year (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Jan	148.00	120.03	83.00	9.00
Feb	82.33	110.00	117.00	85.00
Mar	96.00	32.00	92.00	199.00
Apr	182.00	63.00	130.00	100.00
May	204.00	127.00	44.00	140.00
Jun	112.00	46.50	30.00	74.00
Jul	102.67	114.00	202.00	97.00
Aug	146.33	156.00	240.00	18.00
Sep	72.00	18.67	68.00	18.50
Oct	81.50	170.00	28.00	107.00
Nov	243.00	109.12	65.00	15.00
Dec	55.00	254.00	5.00	24.00
Average	127,07	110,03	92,00	73,88
Total	1 524.83 mg / l	1 320.32 mg / l	1 104.00 mg / l	886.50 mg / l

Two-way ANOVA (Appendix T) was conducted to determine whether there is any significant difference between the suspended solid results of the four production years. The conclusion is that there is no significant difference at the 5% confidence level between years ($p = 0.251$) and also no significant difference at the 5% confidence level between months ($p = 0.754$).

2010 Suspended solids $WF_{proc.grey}$ = L / (C_{max} – C_{nat})
= 1 524 mg / litre / (500 mg / litre – 100 mg / litre)
= 3.81 mg / litre SS for production year 2010

2011 Suspended solids $WF_{proc.grey}$ = L / (C_{max} – C_{nat})
= 1 320 mg / litre / (500 mg / litre – 100 mg / litre)
= 3.30 mg / litre SS for production year 2011

2012 Suspended solids $WF_{proc.grey}$ = L / (C_{max} – C_{nat})
= 1 104 mg / litre / (500 mg / litre – 100 mg / litre)
= 2.76 mg / litre SS for production year 2012

2013 Suspended solids $WF_{proc.grey}$ = L / (C_{max} – C_{nat})

= 886.50 mg / litre / (500 mg / litre – 100 mg / litre)

= 2.22 mg / litre SS for production year 2013

5.12 PROCESS WATER FOOTPRINT ANALYSIS

According to Young (2005), most methods of water valuation fit into two broad categories that differ in the basic mathematical procedures:

- Inductive techniques: using a formal statistical or econometric method
- Deductive techniques: involved logical process to reason from general remises to particular conclusion

In this study the inductive/statistical method was used to determine the footprint of the manufacturing company and deductive techniques were used to reason the improvement plans for the beverage manufacturing company.

The same unit of measure, as per carbon footprint, was used for the water footprint of the beverage manufacturing company, namely litre unit produced and not consumed, as per Table 5.28.

Table 5.30: Blue - and grey water footprint (Beverage manufacturing company data)

Production year	2010	2011	2012	2013
Blue water footprint l/l	5.25	5.10	5.94	6.42
Grey water footprint l/l	0.03	0.05	0.09	0.18

Both the total blue and the grey water footprint are the highest in production year 2013. The lowest production volumes were achieved in production year 2013, which may be an indication that the water resources were not optimal managed in production year 2013.

Table 5.31: Grey pollutant water footprint in mg / litre (Beverage manufacturing company data)

Grey pollutant WF and production year	2010	2011	2012	2013
Total COD mg / l	12.69	5.05	8.44	5.77
Total phosphates mg / l	0.70	0.21	0.29	0.61
Total nitrates mg / l	0.05	0.05	0.04	0.07
Total suspended solids mg / l	3.81	3.30	2.76	2.22

Based on the statistical tests conducted in this study, there is no specific trend for the pollutant grey water footprint, which may be an indication that the pollutants are not related. If one pollutant increases or decreases, it will not necessarily have an effect on any of the other pollutants. However, further analysis are recommended.

5.13 BENCHMARKING FOR A PRODUCT WATER FOOTPRINT

A study that was conducted in 2012 indicated a decrease of 4% of water use ratio for all types of beverage manufacturing organisations (BIER, 2013). The water use ratio decreased from 2.92 l/l to 2.69 l/l. The improvement in water efficiency over the study period corresponds to industry-wide water use avoidance of approximately 65 billion litres in 2012 (BIER, 2013). In all the beverage manufacturing companies that participated in the BIER study – and considering the carbonated beverage facilities – a decrease of 69% of water use ratio was noted (BIER, 2013). The carbonated beverages companies in the BIER study showed a drop from 2.13 l/l water use ratio to 2.02 l/l.

SABMiller set a target of reducing operational water use per litre of beer by 25% by 2015 (SABMiller, 2009). The initiative will reduce their consumption to an average of 3.5 litres of water to make a litre of beer. In 2008 this figure was 4.6 litres and the industry average was 5 litres (SABMiller, 2009). In March 2014 an average water efficiency ratio of 3.5 hl/hl was reached (SABMiller, 2014). Across Europe, Latin America and Asia Pacific a total of 14 breweries used 3.0 hl/hl or less to produce one hl of beer (SABMiller, 2014).

Coca-Cola reduced the water footprint from 2011 to 2013 from 2.16 l/l to 2.08 l/l (Coca-Cola, 2014).

The Heineken 2013 sustainability report indicated a reduction in water consumption from 4.1 hl/hl to 3.9 hl/hl in 2013. This reduction in 2013 is a 20% reduction from the 2008 baseline year. Forty-four of their production facilities are already below 3.7 hl/hl, which represents 45% of their total production volume globally in 2013 (Heineken, 2013).

According to Ercin *et al.* (2010), the total water footprint of a sugar-containing beverage averaged between 169 and 309 litres, all the other ingredients and inputs were kept constant, only the amount of origin of sugar changed.

The Dr Pepper sustainability report of 2014 indicated that in 2011 a total of 3.1 billion gallons of water was used to produce 1.6 billion gallons of product. This equates to 1.97 gallons of water used per gallon of finished product. The waste water discharge (grey water footprint) was approximately 1.4 billion gallons, which equates to 0.88 gallons per gallon of finished product produced. The 2014 report indicated that 2.05 gallons of water was used to produce a gallon of finished product and 0.88 gallons of waste water per finished product produced (Dr Pepper Snapple Group, 2014).

A study that was conducted by BIER in 2013 on 18 beverage companies that reported the total amount of water usage per liter produced. The beer companies used 3.65 l/l produced, the winery companies used 4.09 l/l produced and the bottling companies produced 1.95 l/l produced. The bottling companies include CSD, juice and bottled water production. The water usage specific to CSD companies was 2.64 l/l produced (Nelson & Christenson, 2014). The operational footprint for producing 1 litre of soymilk was 0.9 litres and the water footprint, including the supply chain, was 297 litres of water to produce 1 litre of soy milk (Ercin, Aldaya & Hoekstra, 2012). The total amount of water required to produce a glass of red wine was 120 litres and the total net operational water footprint for a brewery in South Africa was found to be 155 litres of water for 1 litre of beer (Van Vuuren, 2012).

The specific water intake for soft drinks in the South African market was calculated as 2.7 litres in 1987, of which the total process water was 1.08 litres (Binnie & Partners, 1987). The specific effluent volume was 1.72 litres, of which the COD was 3.80 kg/m^3 and suspended solids 0.48 kg/m^3 (Binnie & Partners, 1987). A study was conducted based on the South African water footprint assessment and a major brewery was found to discharge approximately 42 200 tonnes of effluent per week. The breakdown of effluent is 74 tonnes of COD, 32 tonnes of suspended solids, 67.2 tonnes of total dissolved solids and 56 kg phosphates per week (Skivington, 1997).

Table 5.32: Benchmarking between international beverage companies and the beverage manufacturing company (Sustainability reports and beverage manufacturing company data)

Production year and company	**2011**	**2012**	**2013**
BIER l/l	-	2.69	2.02
Coke Cola l/l	2.16	2.12	2.08
SABMiller l/l	4.13	4.0	3.5
Heineken l/l	4.3	4.1	3.1
Dr Pepper l/l	1.97	2.0	2.05
Beverage company l/l	5.10	5.94	6.42

The beverage company water footprint is much higher than any of the other international beverage companies. The Dr Pepper water footprint is also increasing year on year, based to the increase of production volumes (Dr Pepper Snapple Group, 2014). This is an indication that the beverage company should investigate the reasons for the higher water footprint. It must be noted that the calculation method for the benchmarking companies is not known and this can also contribute to the difference in water footprint results.

5.14 SUMMARY

Knowing the carbon and water footprint of products helps companies understand where the highest emissions are and how to reduce emissions and water usage. No resource is more vital to humanity than water. It has been noted that the beverage company's carbon footprint is much greater with that of some of the international benchmarking companies. The total emissions for CO_2 gas into the atmosphere is the highest in terms of the Scope 1 carbon footprint and electricity in terms of Scope 2 for the beverage company.

Yet as the demand for safe water rises, the supplies are shrinking. Today, 70% of the earth's surface is covered by hundreds of major bodies of water, but less than 3% of these are fresh water – the remainder is sea water (Martin, 2006).

This study noted that the beverage company's carbon footprint is substantially larger when compared with that of some of the international piers. The total emissions for the CO2 gas into the atmosphere is the highest in terms of Scope 1 carbon footprint and electricity in terms of Scope 2 for the beverage company.

It is essential that the beverage company investigate the high water footprint and ensure measures are put in place to reduce the grey water footprint. Possible reduction plans are discussed in Chapter 6.

CHAPTER SIX: DISCUSSION AND RECOMMENDATIONS

6.1 INTRODUCTION

The food and beverage companies in South Africa are vulnerable to climate challenges because their businesses are based on the intersection of food, water and energy. The population growth and changing consumer preferences put increased pressure on the companies to deliver more food, which increases the impact on the climate due to increase emissions and water usage. As per the Ceres Roadmap, the food and beverage sector improved its carbon performance since the 2012 sustainability report, but now companies need to focus deeply on water challenges and how to sustain water resources (Ceres, 2015). To sustain our resources and reduce climate change, a 50% improvement in energy efficiency and a 25% lower carbon footprint must be reached globally by 2020 to ensure progress towards sustainability (Lubber, 2010). Companies that will be the best positioned in the 21st century are those that will thrive in becoming low-carbon producing companies and prevent resource increases in an already resource-constrained global economy (Lubber, 2010).

A study conducted by BIER in 2013 on 1 700 beverage facilities (section 2.3.11) across six continents noted that the water and energy usage of the beverage industry decreased over the few years up to reporting in 2013 (BIER, 2013). Over the period 2010-2013, the water use ratio decreased by 70% and energy use ratios decreased by 66% for all the facilities (BIER, 2013).

In this chapter the results of the above carbon and water footprints are discussed and recommendations are made for consideration by the beverage company with the aim of the reduction of its carbon and water footprints. The beverage company should consider reduction plans to be able to compete against both international and local companies and to be acknowledged as leading company in the 21st century.

The success for any system requires the commitment and resources from top management and therefore the carbon and water footprint reduction strategy must start with the Board of Directors and be implemented throughout the company and follow through to the ground level of the company. The climate policy is created based on the climate strategy and implemented at operational level, which includes training on all levels and managing climate change via yearly staff performance measures (Stoffberg & Prinsloo, 2009).

6.2 LIMITATIONS TO THE RESEARCH

Various limitations to this research were found and should be considered for further studies. Currently the beverage company has no carbon or water footprint reduction targets in place for future analysis, therefore the outcome of this research could not be compared against previous set reduction targets. The beverage company should use the information in this dissertation as a benchmark for future in-house comparisons and external benchmarking. The limitations that were experienced are noted below, and some recommendations are made:

- No sales data were available to verify the assumptions regarding lower customer demand in winter seasons. Statistical data did indicate that the production in the winter months are lower than summer months but the full reason for the lower demand in relation to customer demand could not be established. In future, sales data should be requested from the head office when the beverage company wishes to prepare a report on its carbon or water footprint.
- No daily figures were available for emission and water sources and therefore the statistical analysis was limited to monthly and yearly data only. The beverage company should invest in resources to ensure that daily figures are available that would assist with footprint calculation and have to act when the specific process emissions are above the suggested levels.
- There are currently no in-line CO_2 meters to determine the CO_2 usage per production sequence. The manufacturing company can benefit from in-line meters, which will identify the production sequence with the highest CO_2 loss during production.
- Currently the daily CO_2 usage is measured against an electronic inventory system but no actual corrections are made on the system by verifying the total tonne in the CO_2 storage tanks. CO_2 usage is consolidated at month end and only then can possible action be taken if a difference of concern is noted.

- There were no data available for the LPG production year 2011. This provides a skewed outcome in this current study since production year 2010 is the lowest in LPG emissions. Production year 2011 was the year with the second highest production volumes, thus the assumption could be made that the LPG emissions must be in line with production volumes. The current ISO 14001 inventory system should be verified frequently to ensure that all necessary data are available and current.
- The natural gas data for production year 2012 were not available from January to April; therefore production year 2012 was also the lowest in boiler emissions. The still beverage production was the highest in production year 2012 and since still beverages production is related to heat generation, it could be assumed that 2012 boiler emissions are also plausibly to be the highest.
- Currently two production facilities are on the site and the electricity usage was calculated on 60% of total electricity usage of the entire site. It could not be established on what basis the 60% usage was determined. The data could have been more accurate if in-line electricity meters were available to determine the usage per production facility on the site.
- Currently only one water meter is in place to measure the incoming water into the site and another meter that measures the treated water used. The exact amount of water used within the utilities could not be established. The CIP and pasteurisers contribute to the total water usage and loss. If meters were in place, it could have been established which system and or production sequence contributed the most to water loss and preventative measure could have been put in place.
- No data on costs were available for both the carbon and water footprints per emission source. The cost should be used to determine the feasibility of the reduction recommendations noted in the dissertation. A report conducted by the South Africa Department of Energy (2013) indicated that the average tariff for LPG gas is R8.75/kg. If the beverage company can introduce a 5% reduction from the 2013 LPG usage of 120 799 kg at R8.75, the company could have save a total of R52 845 for this year on LPG usage.

A carbon and water footprint was determined with the current information at hand, but a more accurate footprint could have been determined if all the necessary measures were in place as stipulated above.

6.3 PRODUCTION VOLUMES

The statistical analysis presented in Chapter 5 indicates that there is a significant difference between winter and summer months and the total volume produced between the winter months for all four production years. The assumption was made that the data for winter months are based on customer demand/sales demand, but this assumption was made without having actual sales data. It is possible that the production in the winter months is lower because maintenance, projects and improvements in the beverage manufacturing company are always planned on all the production sequences during the winter months. The assumption is that one of the reasons for the scheduling of the packaging is that the beverage plant knows that winter months are much lower in production than summer months. Furthermore, consumers regard cold beverages as non-essential and therefore they do not buy cold beverages in the winter months (Mack, 2013). The competition from low-cost smaller players that offer beverages at much lower prices and take the market share in lower segments could also contribute to the drop in sales of cold beverages (Mack, 2013). A typical example is that a 2 litre bottle of Coca-Cola costs between R14.00 and R16.00 and a generic 2 litre cola costs between R8.00 and R11.00 via shopping online. The aforementioned variables should be considered when analysing the causes in the reduction of production volumes between May and August of each year.

The CSD production volumes were much higher than the still beverage production volumes mainly because CSD market share is more than the still beverage market share. A decline was noted in the total CSD production volumes as from production year 2010 and in the same year an increase in the still beverage volumes was noted. Industry confirmation of these production trends, is also reported by Coca-Cola where the still beverages are out-performing their CSD volumes globally (Bailey, 2015). According to Zegler (2013), carbonated soft drink manufacturers in the USA are experiencing economic constraints because consumers are making healthier choices. Furthermore, they compare the prices of products and tend to go for cheaper products, which is another reason for the reduction in carbonated beverages for the local beverage company. Immediate consumption packs like 330 ml cans and 500 ml PET bottles need to be refrigerated and can be instantly consumed by an individual. However, the larger pack sizes, for example 2 litre PET products, are bought for use by multiple consumers who find it a better value for money option (Mack, 2012). Therefore, the 2-litre production at the Beverage company on sequence A and E is higher than the other production sequences.

Production sequence B decreased in CSD production from production year 2010–2013 but an increase in still beverage was noted on sequence B. The increase in still beverages can also contribute to higher electricity and water usage due to the pasteurisation process for still beverages.

The production sequence that showed the highest increase of production volumes was sequence C. Still beverages and new packaging sizes, in the 1.5 litre PET bottle, were introduced on this sequence and the 1.5 litre bottle was mostly promoted in the rural areas of South Africa.

The production volumes on sequence D were dramatically reduced due to low sales demand for this product. A business decision was made in 2011 to sell the production sequence D but the actual sale was only processed late in 2014. Production volumes were only planned on sequence D once head office approved the production plan, which according to the sales forecast, resulted in the reduction in volumes over the four years.

Production sequences A and E produce most of the carbonated soft drink beverage volume within the beverage manufacturing company. Statistical analysis indicated no significant difference between production years, but rather between months of these two sequences. This difference can be linked to maintenance and projects scheduled on each sequence but during different production months.
The beverage company should consider all the information related to production volumes during the production planning process. During winter months stock levels of raw and packaging material should be limited. Employees should be requested to take leave in that period. CSD production should be strategically planned on

sequence A especially during winter months because of the higher electricity usage of sequence E, as this could result in a saving of electricity in the lower production months. The still beverage production is increasing year on year and this might increase emissions in the future.

6.4 CARBON FOOTPRINT DISCUSSION

6.4.1 SCOPE 1

CSD production volumes indicated no significant difference in comparison to total CO_2 lost within the process. This is an indication to the beverage company that when production increases or decreases, the CO_2 lost will be in line with production volumes. It was noted that the CO_2 lost during production year 2013 (3 467 303 kg; section 5.8.1) was not as erratic as the other production years. The assumption can be made that all the other production years' maintenance was scheduled for the CO_2 storage tanks, which could contribute to the CO_2 emissions and loss. Production year 2013 was the only year in which no maintenance was scheduled and it could have contributed to the fact the CO_2 emissions were constant during production year 2013. If one considers the CO_2 emissions from production year 2011–2013 between production month April to July, the total savings in production year 2013 was 12% compared to production year 2011 and 18% compared to production year 2012. This is an indication that if the maintenance on the CO_2 tanks is not properly managed, a maximum of 18% CO_2 could be lost between April and July each year based on the current study data presented.

The LPG usage increased every year, except for production year 2012. Not all the LPG emission data were available. The increase of LPG emissions in 2013 was due to the increase of warehouse capacity (345.19 kg LPG gas; section 5.8.1). The total production volumes decreased every year, thus a logical deduction could be that the LPG usage would also decline based on the assumption that the usage is in line with the production volumes. This confirming the additional increase in use of the forklifts for increase in warehouse capacity. Two assumptions are made regarding the LPG gas usage. Firstly, the forklift cylinders are manually filled from the 9 tonnes storage tank and the weight of the cylinders is manually transferred to the record sheets. It is possible that the scales are not calibrated. Secondly, during the filling process, employees may unnecessarily emit the gas within the beverage plant.

An environment-related decision was taken by the beverage manufacturing company to convert the HFO boiler to the natural gas boiler. As per Table 5.10 (section 5.6.3) the average difference between HFO and natural gas emission factors is 0.0424 CO_2e / kg usage. If 1 000 kg of HFO is used an average of 283.7 kg CO_2e will be emitted and, in comparison, if natural gas is used an average of 241.25 kg CO_2e will be emitted. This is a total saving of about 15% emissions when natural gas is the preferred boiler heating fuel source. A very similar trend is noted (Figure 5.25; section 5.6.3) between still beverage production requirements and boiler emissions and the assumption is made that the boiler emissions are related to still beverage production.

6.4.2 SCOPE 2

The statistical analysis for energy consumption indicated a significant difference at a 5% confidence level between production years 2011 (6 287 904 kWh; section 5.8.1) and 2012 (5 083 623 kWh; section 5.8.1) and a significant difference at a 1% confidence level between production years 2011 and 2013 (Figure 5.28; section 5.7). No difference was found between the other production years. This difference is possibly due to the still beverage production increase on sequences B and C as from production year 2011 (Table 5.6; section 5.4). The still beverage production on sequence C was reduced in production year 2013 and therefore there was a significant difference of 1% confidence level between electricity usage from 2011 to 2013 (Figure 5.28; section 5.7).

The increase in still beverage production possibly also contributed to the significant difference in electricity usage in the production years, as noted in Figure 5.28; section 5.7. The beverage company can use this data to plan yearly budgets related to increase electricity usage with the potential increase of still beverage production. With regard to the amount of kWh used per litres produced (Table 5.13; section 5.7), 0.05 kWh was used in 2011 to produce 1 litre of product and in 2012 a total of 0.04 kWh was used to produce 1 litre of product. The average electricity cost of R1.90 / kWh (including VAT) was charged by Eskom to local businesses as per Eskom 2011/2012 financial year tariff charges (Eskom, 2011). This is an indication that an average cost of R0.10 was charged per 1 litre produced in 2011 and R0.08 in 2012. The beverage company saved R0.02 per litre produced in production year 2012.

6.4.3 CARBON FOOTPRINT

The carbon emission threshold difference between the production years investigated was more than 5% (Table 5.16; section 5.8.1) and the new baseline year was set for production year 2013. As per The Climate Registry (2012), the baseline is changed once various factors are changed within the organisation. This entails the change from HFO to a natural gas boiler, additional warehouse capacity and the introduction of the still beverage production. Production year 2010 was originally set as the baseline year for this study but after calculating the difference in emissions, it was decided to change the baseline to production year 2013, a decision that could be considered by the beverage manufacturing company. All the data were available for production year 2013, whilst this is not the case for production year 2010, 2011 and 2012.

The operations of production year 2013 were very similar to those of other years in terms of projects and maintenance and the addition volumes. It was the production year with the lowest total production volume (113 308 869 litres, section 5.2) and the highest CO_2e emissions (89.95 g CO_2e / l; section 5.8.1) per unit produced. This is cause for concern because it indicates that emissions were not managed in production year 2013 to ensure a lower footprint is obtained in relation to the lower volumes. The footprint for each emission was the highest in production year 2013, except for electricity, being production year 2011. The change of boilers and the introduction of still beverages can contribute to the higher electricity usage in production year 2011.

From the data analysed in this study, the beverage company could consider production year 2013 as the worst-case scenario in terms of CO_2e emissions for production and should build on the new baseline year to ensure the following years are more controlled and a lower footprint is achieved. If a company does not have a proper management strategy regarding sustainability and does not ensure that reduction plans are in place, the carbon footprint could increase every year.

6.5 BENCHMARKING FOR A PRODUCT CARBON FOOTPRINT

A key challenge for the packaged food and drinks industry is to adopt sustainable principles and goals whilst addressing cost, performance and market pressures (Coles & Kirwan, 2011). Benchmarking between the beverage manufacturing company and various other international companies is presented below, taking into consideration that the emission factors might differ for the calculations in different countries and that it is not known what emissions were considered when calculating the Scope for the specific international or local benchmarking company. The benchmarking is based on the new baseline year 2013.

Heineken improved their overall energy performance with a reduction from 8.8 kg CO_2e / hl in 2011 to 8.4 kg CO_2e / hl in 2012. This improvement is primarily the result of the energy-saving activities at their production units, but it is also due to an increased share of renewable energy (8.0% of total electricity consumption in 2011, compared with 9.3% in 2012), causing the indirect CO_2 emissions to decrease (Heineken, 2012). The Heineken 2013 sustainability report indicates a further reduction in CO_2 emissions from 8.4 kg CO_2e / hl in 2012 to 7.7 kg CO_2e/hl in 2013; this is a total reduction of 26% compared to the baseline year 2008 (Heineken, 2013). If one converts the beverage manufacturing company data to hectolitre and per kg CO_2e then the beverage manufacturing company's electricity performance is lower than Heineken's, considering the fact that the emission factors does differ from country to country. The achievement of the beverage company is reflected in Table 6.1. A nett reduction is not noted in the beverage company's performance compared to Heineken's performance since the aim of this study was to indicate the carbon footprint of the beverage company to ensure that reduction plans are put in place.

Table 6.1: Comparison of electricity performance between Heineken and the beverage manufacturing company (Heineken sustainability reports 2010–2013 and beverage manufacturing company data)

Company and production year	Heineken	Beverage manufacturing company
2010	9.3 kg CO_2e / hl	4.4 kg CO_2e / hl
2011	8.8 kg CO_2e / hl	5.02 kg CO_2e / hl
2012	8.4 kg CO_2e / hl	4.03 kg CO_2e / hl
2013	**7.7 kg CO_2e / hl**	**4.57 kg CO_2e / hl**

A study was conducted in 2008 on fruit harvesting in South African. The energy consumption of different pack houses varied between 10 and 20 kWh per tonnes packed for grape pack houses. For pome and citrus pack houses the consumption varied between 30 and 45 kWh per tonnes of fruit packed (Blignaut, 2014). The 2013 wine industry sustainability report indicated total emissions of 0.70 kgCO_2e / litre bottle of white wine produced and 0.80 kgCO_2e / litre bottle for red wine produced (Blignaut, 2014). This calculation includes Scope 1, Scope 2 and Scope 3. Considering the fact that Scope 3 was not calculated for the beverage company, the beverage company achieved 0.1 kgCO_2e / litre beverage produced (Table 5.15) in production year 2013. Scope 3 contributed the most to CO_2 emissions, therefore it seems as if the beverage company is achieving better emissions, but it might not if Scope 3 was calculated for the beverage company.

According to the Dr Pepper sustainability report of 2014, the electricity usage in 2011 was 270 million kWh, yielding a rate of 0.17 kWh per gallon of finished product. At the end of 2013 the usage was 254 million kWh at a yielding rate of 0.16 kWh per gallon of finished product (Dr Pepper Snapple Group, 2014). The conversion was done from litres produced at the beverage company to gallons to conduct the benchmarking between Dr Pepper and the beverage company electricity usage.

Table 6.2: Benchmarking between Dr Pepper and the beverage manufacturing company (Dr Pepper Snapple Group, 2014 and beverage manufacturing company data)

Company and production year	Dr Pepper	Beverage manufacturing company
2011	0.17 kWh/gallon of finished product	0.19 kWh/gallon of finished product
2013	0.16 kWh/gallon of finished product	0.17 kWh/gallon of finished product

A study conducted by BIER in 2013 on 18 beverage companies reported the total amount of energy usage in MJ (Megajoule) per litre produced. The beer companies used 1.23MJ / litre produced, the winery companies used 1.67MJ / litre produced and the bottling companies produced 0.4MJ/ litre produced. CSD, juice and bottled water production were taken into account in the above-mentioned study. Companies specific to CSD production indicated a usage of 0.36 MJ / litre produced (Nelson & Christenson, 2014). The electricity usage was converted from kWh to MJ to benchmark the beverage company electricity usage with the CSD BIER companies.

Table 6.3: Benchmarking BIER CSD companies against the beverage manufacturing company (Nelson & Christenson, 2014 and Beverage manfacturing company data)

Company and production year	BIER CSD companies	Beverage manufacturing company
2013	0.36 MJ/ litre product produced	0.16 MJ / litre product produced

*(1 kWh = 3.6 MJ)

It is noted that the beverage manufacturing used less electricity than the CSD company reported by Nelson and Christenson (2014) and that the electricity emission factor and type of energy source had an impact on the electricity usage in the BIER CSD companies.

6.6 RECOMMENDATIONS FOR REDUCTION IN CARBON EMISSIONS

Recommendations are based on reduction of the carbon footprint and thus to operate in a less carbon-intensive way. It is recommended that the company achieve increasing carbon efficiency by applying low-carbon technology and after company behaviour. This could ensure less GHG emissions per unit of production (Ercin & Hoekstra, 2012). Some companies have achieved dramatic GHG reductions by implementing a single initiative that significantly altered their emissions profile (Hoffman, 2010). The beverage company should focus reduction initiatives on those processes identified by the assessment as being of most concern and initiatives that deliver the greatest possible saving for the lowest cost (BSI, 2011). Some potential savings in relation to the beverage manufacturing company are discussed below. No one emission source is singled out but rather various reduction projects are mentioned.

By managing and controlling CO_2 emissions the beverage company can implement daily cycle counts at the CO_2 storage tanks to ensure that the maintenance team can act as soon as an increase in CO_2 loss is noted. Another way of managing the CO_2 loss is to determine which production sequence contributes the most to CO_2 emissions. The beverage company can install CO_2 measuring meters at each production sequence to determine the usage per line and act where necessary to reduce the CO_2 loss and for potential savings. The daily CO_2 storage tank figures can be compared with each line CO_2 meter reading. The density of CO_2 is 1.98g / l (Yang, 2001). The beverage company calculates the amount of CO_2 needed per product produced by multiplying the density of carbon dioxide (1.98g / l) and the unit volume and the actual gas volume to be achieved. For example: to produce 1 litre of PET product with a 4.00 g/litre gas volume, a total of 7.92 g CO_2 gas is required (1.98 x 4). The beverage manufacturing company can act immediately if they identify a production line with excessive CO_2 loss based on the total CO_2 required to produce a litre of product.

It is recommended that the beverage manufacturing company install thermal covers around steam pipes, pasteurisers and CIP storage tanks to prevent excessive heat or steam condensate that contributes to loss of heat that is generated by the boiler (Galitsky, Martin, Worrel & Lehman, 2003). The insulated covers help to prevent heat loss in the water that is transferred back to the boiler. Every 10% of hot water returned to the boiler reduces the energy usage by 1.5% (Brewers Association, 2014). Such an initiative will assist with reduction in boiler emissions because if the energy loss at sequence B and C pasteurisers is reduced, the energy generation at the boiler will be reduced. Based on the total kWh energy usage for the boiler for all four years (section 5.8.1) it is noted that an approximate total of 1 172 346 kWh could have been saved over the four-year period at the beverage manufacturing company with a 10% reduction achieved by installing thermal covers.

There are many new CIP chemicals on the market that are efficient at lower CIP cleaning temperatures (Jude & Lemaire, 2013). The still beverage requires more frequent CIP; thus, by reducing CIP cleaning temperatures, emissions can be reduced. New innovations of CIP systems can reduce energy usage up to 20% and reduction of 20% in production down time (Jude & Lemaire, 2013).

Human behaviour to prevent forklifts from idling when not in operation can reduce emissions. The beverage manufacturing company should ensure that employees keep to the speed limits to prevent an increase of emissions. Furthermore, it is suggested that the company investigate the benefit of battery-operated forklifts.

The Scope 2 is based on the electricity grid emission factor from Eskom; thus the manufacturing company would not be able to reduce the grid factor. The manufacturing company should focus on possible reduction plans within the manufacturing company to reduce the quantity of electricity sourced from Eskom. Such reduction plans could include the change of conventional light bulbs throughout the facility and motion-sensor office lights. One of the largest Coca-Cola plants in North America, Brampton in Ontario, converted to an energy-efficient lighting system that uses 50% less energy and provides 50% more light. These new fixtures also operate on motion sensors for even greater savings (Wong, 2011). Thus the beverage company may expect some reductions based on the example of Coca-Cola if motion sensor lights are installed.

The manufacturing company should understand the base load and peak load from the local municipality to implement in-house reduction processes. Electricity cannot be stored, and could therefore be used as it is generated. It is important that the amount of electricity needed at any point in time should be matched by the amount generated. Since electricity demand is not constant, different types of power stations are required to meet this fluctuating demand. Two main categories of power stations can be identified: *base load* stations which supply electricity around the clock and *peak load* stations which can react swiftly to sudden increases or decreases in demand (Eskom, 2014).

Peak load occurs in the early morning for both domestic and industrial demand and early evening for mainly domestic demand (Eskom, 2014). If high electricity usage equipment is started all at once, a voltage transient occurs. A voltage transient can be defined as an unexpected or unanticipated change in voltage caused by an unpredictable and sometimes unprecedented occurrence (Winters, 1976). To prevent voltage transients the high electricity usage equipment can be switched on at different times. During the transient phase a significant phase difference occurs between voltage and current load (Ware, 2006). It is recommended that the use of service equipment be staggered during production start-up to reduce the peak in electricity usage. This method reduces the maximum load because equipment has its own maximum electricity output during the start of the equipment. If all the equipment is switched on at the same time, the electricity peak load increases, which causes higher usage. The manufacturing company could also install meters for both the facilities on the beverage site to determine the correct amount of electricity usage for the beverage plant. The current calculation is based on 60% usage of the total electricity bill. This noteworthy difference can be corrected by introducing a power correction factor. Based on the above it would be in the best interest of the manufacturing company to stagger equipment during production start-ups.

One of the easiest ways to reduce greenhouse gas emissions is to change the attitudes of the employees. A simple example is to ensure that all lights and air conditioners are switched off during the evening and at the weekends and to install solar water heaters for the ablution facilities used by all employees. The City of Johannesburg listed its first green bond on the Johannesburg Stock Exchange. The programme includes the installation of 43 000 solar water heaters, which will save the equivalent of 22.5GW of electricity per annum, which is enough to run a small town (Williams & Blumenthal, 2014).

The White Paper on Renewable Energy (2003) set a target of 10 000GWh of energy to be produced from renewable energy sources, mainly biomass, wind, solar and small-scale hydro by 2013 (Department of Minerals and Energy, 2003). The manufacturing company could launch a project to understand the cost implication and benefit of running certain processes from solar panels.

It is suggested that the beverage company set a target for reducing the carbon footprint by a certain time. This reduction target should be communicated to all employees and behavioural training can be done to ensure that employees' behaviour is aligned to the target for the company. The current ISO 14001 aspect targets are based on production produced against each emitter and not in g CO_2e. The information from this study should be considered in setting carbon footprint targets per emission source and for the next five years up to 2020. Long term targets are also recommended to ensure that a reduction plan is in place to reduce the emissions over decades and align with national and international policies and best practises. Recommended targets per litre produced based on the current information on hand are indicated in Table 6.4.

Table 6.4: Carbon footprint reduction targets for 2020 (Beverage manufacturing company data).

Emission source	**Current emission**	**Target reduction by 2020**
CO_2	34.18 g CO_2e / litre	32.47 g CO_2e / litre
LPG	0.0030 g CO_2e / litre	0.0029 g CO_2e / litre
Boiler	10.06 g CO_2e / litre	10.01 g CO_2e / litre
Electricity	45.71 g CO_2e / litre	43.43 g CO_2e / litre

The targets as per Table 6.4 were calculated based on the new baseline year 2013 and a 5% threshold reduction as per section 5.8.1. The total reduction was based on a 5% reduction by production year 2020. The beverage company should consider the reduction recommendations as stated to ensure the targets can be achieved by 2020. The company should consider verification of all the GHG emission data by a third party and may consider engaging in GHG emission trading programmes (Stoffberg & Prinsloo, 2009). Trading programmes are used, in some instances, by companies to offset their own emissions by trading with other companies (Stoffberg & Prinsloo, 2009).

6.7 WATER FOOTPRINT DISCUSSION

6.7.1 BLUE WATER FOOTPRINT

There is a growing demand for new approaches towards sustainable water use and resources (Ercin & Hoekstra, 2012). The 2013 CDP report on Nestlé indicated that the Western Cape region in South Africa experienced severe drought over the past few years, which had a direct impact on their operations (CDP, 2013).

The blue water footprint per unit produced was calculated by dividing the total incoming water with the total amount of litres produced in the beverage facility. As per the carbon footprint, the blue water footprint per unit produced was the highest in production year 2013 (6.42 litres of blue water/litre production; section 5.11). Production year 2011 (5.10 litres of blue water/litre production; section 5.11) was the lowest blue water footprint per unit produced. In production year 2011 re-engineering was done on the production lines to ensure that all water used in the on-line rinsers is re-used in the water treatment system. This could be the reason for the lower footprint based on the water saving initiative in 2011. The increase in footprint from production year 2012 (5.94 litres of blue water/litre production; section 5.11) is related to the increase of still beverages in the beverage facility. It is recommended that the CIP process be carried out more frequently with still beverage and increase of CIP increase the water usage. The pasteurisation processes for the still beverage also contributes to more water usage. The assumption is made that unnecessary water losses occurred in production year 2013 because both CSD and still beverage production were lower in that year. The water saving initiative related to the re-use of rinser water was not properly maintained over the years, which led to treated water being dumped down the drain during production and not re-used in the water treatment system.

6.7.2 GREY WATER FOOTPRINT

The grey water footprint per unit produced was determined by dividing the total effluent water by the total litres of product produced. It is noted for the grey water footprint that production year 2013 (0.18 effluent litre / litre production; section 5.11) achieved the highest grey water footprint for all four-production years. Behaviour is the main reason for the increase in grey water footprint. During down time, projects and/or maintenance on production lines, the on-line rinsers are not shut down, which causes a direct loss in water down the effluent drain. The beverage manufacturing company should consider behavioural training sessions with employees to ensure that during down time and/or when there is no production planning, equipment is shut down and resources are saved.

It was noted that the tunnel pasteurisation unit on sequence B was leaking for a great part of production years 2012 and 2013 due to a cracked base plate, which caused a direct loss in blue water and an increase in grey water. The pasteurisation unit on sequence C is designed to dump all water automatically when the line is in shut down for CIP process.

The grey pollutant water footprint was calculated per pollutant load for each specific year and no specific trend was found to indicate which year was the highest on all four pollutant loads. Currently the beverage company is paying the most penalties for high COD levels in the effluent water when more than 5000mg COD levels are detected by the municipality. The COD (12.69 mg / litre) and suspended solids (3.81 mg / litre) was the highest in production year 2010 due to the new sugar dissolving system that was implemented and that caused sugar losses during the commissioning phase.

6.7.3 WATER FOOTPRINT

There have been no major changes within the beverage manufacturing company since 2010 with regard to the water and effluent system, as seen in the carbon footprint outcome, but an increase in production since production year 2011 has been noted. An increase is noted on both footprints as from production year 2010, considering that production year 2012 was the production year with the highest production volume (126 147 637 litres, section 5.2). The baseline for the water footprint and pollutant grey water footprint was set at production year 2012, due to the increase of production volumes. Production year 2013 was the production year with the lowest production volumes (section 5.2) and with the highest blue and grey water footprint. This is an indication that the water resources were not properly managed during production year 2013 because one would assume that with lower production volumes, the blue and grey water footprint must be lower.

Table 6.5: Water footprint summary (Beverage manufacturing company data)

Water footprint in litre water / litre production	**2010**	**2011**	**2012**	**2013**
Blue WF l/l	5.25	5.10	5.94	6.42
Grey WF l/l	0.03	0.05	0.09	0.18
Pollutant grey water footprint in mg	**2010**	**2011**	**2012**	**2013**
Total mg COD	12.69	5.05	8.44	5.77
Total mg phosphates	0.70	0.21	0.29	0.61
Total mg nitrates	0.05	0.05	0.04	0.07
Total mg suspended solids	3.81	3.30	2.76	2.22

In setting reduction targets for 2020, the beverage company should consider the information in Table 6.5 to ensure that targets are in line with the carbon footprint reduction time-frame and a goal of 5% reduction.

Table 6.6: Water footprint reduction targets for 2020 (Beverage manufacturing company data)

Water footprint	**Current footprint**	**Target reduction by 2020**
Blue water footprint	5.94 litre blue water/litre production	5.64 litre blue water/litre production
Grey water footprint	0.09 litre grey water/litre production	0.085 litre grey water/litre production
COD pollutant footprint	8.44 mg COD	8.02 mg COD
Phosphates pollutant footprint	0.276 mg phosphates	0.276 mg phosphates
Nitrates pollutant footprint	0.038 mg nitrates	0.038 mg nitrates
Suspended solids pollutant footprint	2.62 mg suspended solids	2.62 mg suspended solids

6.8 BENCHMARKING FOR A PRODUCT WATER FOOTPRINT

A study that was conducted in 2012 indicated a decrease of 4% of water use ratio for all types of beverage manufacturing organisations (BIER, 2013). In the study the water use ratio for all types of beverage organisations decreased from 2.92 l/l to 2.69 l/l. The improvement in water efficiency over the study period corresponds to industry-wide water use avoidance of approximately 65 billion litres in 2012, enough water to fill New York's Empire State Building 62 times (BIER, 2013). All the beverage manufacturing companies that participated in the BIER study and considering the carbonated beverage facilities, a decrease of 69% of water use ratio was noted (BIER, 2013). The carbonated beverages companies in the BIER study showed a decrease from 2.13 l/l water use ratio to 2.02 l/l.

SABMiller set a target of reducing operational water use per litre of beer by 25% by 2015 (SABMiller, 2009). The initiative will reduce their consumption to an average of 3.5 litres of water to make a litre of beer. In 2008 this figure was 4.6 litres and the industry average was 5 litres (SABMiller, 2009). In March 2014, an average water efficiency ratio of 3.5 hl/hl was reached (SABMiller, 2014). Across Europe, Latin America and Asia Pacific 14 breweries used 3.0 hl/hl or less to produce one hl of beer (SABMiller, 2014). Coca-Cola reduced their water footprint from 2011 to 2013 from 2.16 l/l to 2.08l/l (Coca-Cola, 2014).

The Heineken 2013 sustainability report indicated that their water consumption was reduced from 4.1 hl/hl to 3.9 hl/hl in 2013. This reduction in 2013 was a 20% reduction from the 2008 baseline year. Forty-four of their production facilities were already below 3.7 hl/hl, which represented 45% of their total production volume globally in 2013 (Heineken, 2013).

In 2010 it was reported (for all sugar-containing product as per the study) that the total water footprint of a sugar-containing beverage averaged between 169 litres water/kg sugar produced and 309 litres water/kg sugar produced. All the other ingredients and inputs were kept constant; only the amount of origin of sugar had changed (Ercin *et al.*, 2010).

The Dr Pepper sustainability report of 2014 indicated that in 2011 a total of 3.1 billion gallons of water were used to produce 1.6 billion gallons of product; this equates to 1.97 gallons of water used per gallon of finished product. The waste water discharge (grey water footprint) was approximately 1.4 billion gallons, which equates to 0.88 gallons per gallon of finished product produced. The 2014 report indicates that 2.05 gallons of water was used to produce a gallon of finished product and 0.88 gallons of waste water per finished product produced (Dr Pepper Snapple Group, 2014).

A study was conducted by BIER in 2013 on 18 beverage companies that reported the total amount of water usage per liter produced. The beer companies used 3.65 l/l produced, the winery companies used 4.09 l/l produced and the bottling companies produced 1.95 l/l produced. The bottling companies produced CSD, juice and bottled water. The water usage specific to CSD companies was 2.64 l/l produced (Nelson & Christenson, 2014). The operational footprint for producing 1 litre of soymilk was 0.9 litres and the water footprint, including the supply chain, was 297 litres of water to produce 1 litre of soymilk (Ercin *et al.,* 2012). The total amount of water required to produce a glass of red wine was 120 litres and the total net operational water footprint for a brewery in South Africa was found to be 155 litres of water for 1 litre of beer (Van Vuuren, 2012).

The specific water intake for soft drinks in South Africa market was calculated as 2.7 litres in 1987, of which the total process water was 1.08 litres (Binnie & Partners, 1987). The specific effluent volume was 1.72 litres, of which the COD was 3.80 kg/m^3 and suspended solids 0.48 kg/m^3 (Binnie & Partners, 1987). A study was conducted based on South African water footprint assessment and a major brewery was found to discharge approximately 42 200 tonnes of effluent per week. The breakdown of effluent is 74 tonnes of COD, 32 tonnes of suspended solids, and 67.2 tonnes of total dissolved solids and 56 kg of phosphates per week (Skivington, 1997).

Table 6.7: Benchmarking between international beverage companies and the beverage manufacturing company (Sustainability reports as mentioned above and Beverage manufacturing company data)

Production year and company	2011	2012	2013
BIER l/l	-	2.69	2.02
Coca-Cola l/l	2.16	2.12	2.08
SABMiller l/l	4.13	4.0	3.5
Heineken l/l	4.3	4.1	3.1
Dr Pepper l/l	1.97	2.0	2.05
Beverage company l/l	5.10	5.94	6.42

The beverage company water footprint is much higher than any of the other international beverage companies. The Dr Pepper water footprint is also increasing every year, based on the increase of production volumes (Dr Pepper Snapple Group, 2013). This is an indication that the beverage company must investigate the reasons for the higher water footprint. It must be noted that the calculation method for the benchmarking companies is not known and this may also contribute to the difference in water footprint results. The results are based on the calculating the water footprint on the water assessment tool*,* but various other types of methodologies are available as per ISO 14046, the Ceres guidelines and other guidelines.

6.9 RECOMMENDATIONS FOR WATER FOOTPRINT REDUCTION

The beverage company should be committed to practices that reduce unnecessary water wastages. One of the behavioural changes that need to be addressed is the proper planning of preventative maintenance on equipment. The on-line rinser and tunnel pasteurisers cause unnecessary water waste and this could have been prevented by ensuring that preventative maintenance is scheduled and followed through. Some of the easiest ways and less expensive ways for the beverage manufacturing company to reduce water usage is to ensure that water measuring meters are installed at all water taps so that only a certain amount of water is used.

One of the largest water saving projects suggested for the beverage company is to launch a project at the water treatment plant. All backwashing water for the sand

and carbon filters can be re-used in the water treatment system. If the beverage company could recover 25% of the backwash water, a total saving of over 200 million litres of treated water could be obtained over the four-year study period. In future, the water in the tunnel pasteuriser could be re-used in the cooling towers to prevent water losses during production. The total volume of the tunnel is 10 000 litres and about 1 800 litres are lost during production, which equates to a total loss of 1 800 litres each time still beverage product is produced on sequence B.

The installation of an effluent plant will assist the beverage company in reducing the effluent penalty charges from the municipality. Effluent systems can reduce pollutants for COD up to 87% and suspended solids up to 86% (Hussain, Sattar, Khan & Nafees, 2013).

6.10 SUMMARY

This chapter provided details of decisions regarding the outcome of the carbon and water footprint. It is evident that production year 2013 was the highest in terms of both carbon and water footprint per unit produced. The baseline year was changed from production years 2010 to 2013 for carbon footprint and for the water footprint the baseline was set to production year 2012, due to the highest production volumes for this year.

It is suggested that the beverage company implement the recommendations to improve the reduction of the current emissions and to give guidelines regarding possible GHG sources and water to consider for future expansions of the beverage company. The most important and one of the quickest ways is to change the footprints are through the change of the behaviour of employees to save resources. The beverage company is currently ISO 14001 certified and they should use this baseline to improve on reduction plans and analyse the current available data in greater detail to identify areas of concern and to act once trends are noted. The beverage company should conduct ISO carbon and water footprint public reporting in line with the ISO 14001 environmental management system. The public reporting should be done every year and the emissions should be measured against the set targets. Improvement plans with a certain percentage reduction over a set time should be considered, from stakeholders up to production floor level.

CHAPTER SEVEN: CONCLUSION AND SYNTHESIS

7.1 INTRODUCTION

In this final chapter the outcome of the reported research is summarised in relation to the aim, which was to determine a carbon and water footprint for the beverage manufacturing company. The chapter also provides the conclusion regarding the carbon and water footprints and the relation to the beverage company and it focuses on specific areas that should be considered for further research and investigation.

7.2 SUMMARY OF FINDINGS

The rationale set out in this research was to determine a carbon and water footprint for a South African soft drink manufacturer and to identify possible emission reduction options based on the outcome of the research. The data from the emission sources and water sources were retrieved from the beverage company and formed the basis of the secondary data used in this research. The results of the data were calculated to determine the carbon and water footprint and to give a perspective to the managers regarding their current sustainability footprint of the beverage company.

The three objectives that were set for this research are summarised below to give an overview of the outcome of the research.

Objective 1: Calculate the carbon footprint for Scope 1 and Scope 2

The secondary data collected from the beverage manufacturing company covered a four-year period from 2010 to 2013. The data were used to calculate Scope 1 and Scope 2 emissions for each emission source (section 3.4). The carbon footprint was expressed as g CO_2e per unit beverage produced (Table 5.15; section 5.8.1). The first baseline year was set to production year 2010 but after the carbon footprint results, were calculated, the baseline was re-set to production year 2013 as a 5% threshold was achieved between the baseline and the other production years. The decision was also based on the fact that production year 2013 was the year in which all the data variables were available for the footprint determination (Table 5.16; section 5.8.1).

The lowest Scope 1 footprint was achieved in production year 2010: a total of 28.27 g CO_2e per litre unit produced was achieved. The highest footprint for Scope 1 was in production year 2013 as 44.25 g CO_2e per unit produced. The higher Scope 1 footprint in production year 2013 was not due to the increase of production volumes, but surprisingly the emissions increased with a decline in production volumes. The total production volumes were the lowest in production year 2013 and the highest carbon footprint per unit produced was recorded for this year.

The lowest Scope 2 footprint, 40.30 g CO_2e, per litre unit produced, was achieved in production year 2012 and the highest Scope 2 footprint, 50.16 g CO_2e per litre unit produced, was reached in production year 2011. In production year 2011 the HFO boiler was converted to a natural gas boiler, which decreased the source emissions. In production year 2012 the electricity usage was more constant and aligned with the total volume of product produced.

The highest g CO_2e footprint per litre unit produced for Scope 1 and Scope 2 combined, 89.95 g CO_2e litre unit produced, was in production year 2013. The lowest combined footprint achieved was 71.83 g CO_2e litre unit produced in 2010.

Production year 2010 was the year with the highest total volume product produced and considering that the highest footprint was achieved in 2013, it provided an opportunity to address the management of resources within the facility. All necessary inventory systems are in place to measure the emissions by source. It is noted that these inventory systems are incomplete, lacking information and the unavailability of daily figures. Measuring and monitoring of daily figures will alert the beverage company when a specific emitter is out of bounds and action can be taken to prevent unnecessary emissions.

Even though the beverage company footprint is increasing every year, the current 2013 carbon footprint is in line when benchmarked against international companies (section 6.5). It is noted that the beverage company can reduce the current 2013 carbon footprint by identifying reduction opportunities, setting reduction targets and managing the current systems in place.

Objective 2: Conduct a water footprint assessment

The water footprint was calculated as blue - and grey water footprint (section 2.3.1) by using the secondary data from the beverage company for production years 2010–2013 (section 3.4). The water footprint was calculated to determine a footprint per unit beverage produced.

The blue water footprint was determined by calculating the total incoming water used against the total litres of product produced, where grey water footprint is used to determine the effluent litres versus total litres produced. Both the blue and the grey water footprint were the highest in production year 2013. The total blue water footprint per unit produced for production year 2013 was 6.42 litres of blue water / litre produced and for grey water footprint it was 0.18 litre of effluent / litre produced.

The lowest footprint achieved was in production year 2011 with a blue water footprint of 5.10 litres of water/litre produced and a grey water footprint of 0.03 litre of effluent / litre produced in production year 2010. In comparing the blue - and grey water footprint of production year 2013 against the other production years it was noted that the blue water footprint increased with over a litre per unit produced and the grey water footprint was six times more than in production year 2010.

The grey pollutant water footprint does not indicate a specific trend on all four pollutants to indicate a specific year that was higher than the other years. The production year 2010 was higher in mg COD and mg suspended solids due to the new sugar dissolving system.

Currently the beverage company does not have a proper grey water footprint inventory management reporting system in place. The amount paid to effluent penalty charges is not properly communicated throughout the company and therefore it is necessary to communicate information to ensure operations management can act when required.

Objective 3: Indicate possible opportunities for reduction for both carbon and water footprint

Various reduction plans were identified in Chapter 6 (sections 6.2.4 and 6.3.3), which will assist the organisation in reducing both the carbon and the water footprint.

The main focus for the beverage plant should be to ensure that all emission and water sources are managed. It is evident that production year 2013 was the highest for both the carbon and the water footprint, but it was the year with the lowest production volumes. Both footprints would be expected to be less considering the lower production volumes. The beverage company is already ISO 14001 certified, which is an indication that tracking of emission and water usage is in place. It is just a matter of trending the data and discussing these aspects more frequently to identify areas of concern as well as continual improvement within the system. It is essential for the beverage company to manage emissions based on the South African government's new Carbon Tax proposal. Water scarcity is problematic; therefore, it is critical to protect this essential resource in current and future production parameters.

7.3 RECOMMENDATIONS FOR FURTHER RESEARCH

The analysis of the literature and the investigation into the carbon footprint of the manufacturing company indicate that the manufacturing company would benefit from additional research on Scope 3 emissions. The Scope 3 carbon footprint calculation was not part of this research. Scope 3 focuses and include the emissions associated with the supply chain, as well as incoming raw and packaging material. One of the major contributions to Scope 3 reductions in terms of packaging is to reduce empty packaging weight and to re-cycle PET, known as r-PET. PepsiCo Beverages Canada introduced the first 100% recycled Eco Green bottle in 2011and the new bottle reduced the carbon footprint with approximately 2.72 million kilograms per year (Mohan, 2011). Companies must have access to supply chain GHG emissions, engage with suppliers on controlling emissions, address the impact of materials and packaging on the climate and improve logistics to reduce emissions (Moffat *et al*., 2013).

The current water footprint was calculated by using the Water Footprint Assessment Manual. The new ISO 14046 Water footprint – Principles, requirements and guidelines was published in 2015. It is recommended that the calculation of the water footprint be based on ISO and that the difference of the two methodologies be determined in this way.

It is recommended that the beverage company should consider behavioural training for employees regarding resource management and should ensure that proper communication channels are in place to report out of control emitters.

7.4 CONCLUSION

It may be concluded from the research that a carbon and water footprint can be established for a beverage manufacturing company within South Africa. In this specific case the baseline was changed from production year 2010 to production year 2013. Production year 2013 was the year with the highest carbon footprint and the lowest production volumes. Both blue - and grey water footprints were also the highest in production year 2013. The carbon and water footprint reduction plans can be put in place once the footprint is known. The research identified areas of improvement for the management team to ensure data measuring is accurate, which will assist with accurate future reduction plans. All resources must be protected for the good of future generations – both human and natural ecosystems. This study has illustrated that with limited emission source emission information a carbon and water footprint as well as reduction plans can be determined. The beverage company has the opportunity to use this information to enhance future reduction and sustainability reporting. Various emission reduction plans have been identified in this study and the beverage company should consider these reduction plans to ensure benchmarking against local and international beverage companies.

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APPENDICES

APPENDIX A: Difference between carbon footprint and water footprint (Ercin & Hoekstra, 2012)

	Carbon footprint (CF)	Water footprint (WF)
What is measured	The anthropogenic emission of greenhouse gases (GHG)	The human appropriation of freshwater resources in terms of volumes of water consumed and polluted
Unit of measure	Mass of carbon dioxide (CO_2)-equivalents per unit of time or per unit of product	Water volume per unit of time or per unit of product
Spatiotemporal dimension	Timing in the year and place of emissions are not specified. It does not matter where and when carbon emissions occur; carbon emissions units are interchangeable.	WFs are specified in time and by location. It matters where and when a WF occurs; WF units are not interchangeable. For some uses, total/average WFs are shown, thus leaving out spatiotemporal specifications.
Footprint components	CF per type of GHG: CO_2, CH_4, N_2O, HFC, PFC, and SF6. Emissions per type of gas are weighted by their global warming potential before adding.	Blue, green and grey WF. If added, the three components are added without weighting.
Entities for which the footprint can be calculated	Processes, products, companies, industry sectors, individual consumers, groups of consumers, geographical areas.	Processes, products, companies, industry sectors, individual consumers, groups of consumers, geographical areas
Calculation methods	**Bottom-up approach:** 1. For processes, products and small entities 2. The method of LCAs. **Top-down approach:** 1. For sector, national and global studies. 2. The method of Environmentally Extended Input-Output Analysis (EE-IOA). **Hybrid approach:** 1. LCA and EE-IOA for products, nations, organisations	**Bottom-up approach:** 1. For processes, product and businesses, but also for sector, national and global studies. 2. The method of bottom-up accounting in Water Footprint Assessment (WFA). 3. For products, the accounting along supply chains in WFA is similar to the accounting in the Life Cycle Inventory stages of LCA studies. **Top-down approach:** 1. For sector, national and global studies. 2. The method of top-down accounting in WFA, which is based on drawing national virtual water trade balances. 3. The method of EE-IOA is used as an alternative.
Scope	1. Direct emissions 2. Indirect emissions from electricity used 3. Other indirect emissions	Always includes direct and indirect WF.
Sustainability of the footprint	Additional information is required to assess the sustainability of the CF. For the planet as a whole, a maximum allowable GHG concentration needs to be estimated, which needs to be translated to CF cap. For specific processes and products, CF benchmarks can be used.	Additional information is required to assess the sustainability of the WF. Per catchment area, freshwater availability and waste assimilation capacity need to be estimated, which form a WF cap for the catchment. For specific processes and products, WF benchmarks can be used.

APPENDIX B: Interview questionnaire

TOPIC: CARBON AND WATER FOOTPRINT FOR A SOFT DRINK MANUFACTURER IN SOUTH AFRICA

Thank you for taking the time to participate in this questionnaire based on a carbon and water footprint, you will remain anonymous. I just need a sample of an audience (in this case management level of an organisation) to use as quantitative date collection for the Masters in Environmental Science at the University of South Africa (UNISA).

• Are you male of female?	
• Are you executive or operational level management?	
• What is your understanding of the term carbon footprint?	
• What is your understanding of the term water footprint?	
• What is your understanding of the term Scope one and Scope two climate emissions?	
• What is your understanding of the term green, blue and grey water footprint?	
• Does your organisation have any emission reduction plans in place? If yes – what are those reduction plans?	
• Can you indicate what type of emission data your organisation collects?	
• Do you have recommendations that will contribute to the organisation reduction plans for both carbon and water footprint?	

APPENDIX C: The classification of in-house emission data (BIER, 2010)

Type of scope	Primary quantitative data	Measuring unit per kilolitre product produced	Verification documents	Direct use and consumption
2	Electricity	Kilowatt hours (kWh)	Financial statements/ Aspect register	The entire beverage process
1	Carbon dioxide (CO_2)	Kilogram (kg)	Financial statements / Aspect register	Incorporated in the beverage
1	LPG	Kilogram (kg)		Forklift trucks
1	Natural gas	Kilowatt hours (kWh)	Aspect register	Boiler
1	Refrigeration gas: 1. Aircon 2. Ammonia	Kilogram (kg)	Financial statements	Refrigeration plant
Blue water footprint	Total incoming municipal water & treated water used in the beverage	Litres (L)	Aspect register / Invoices	Incorporated in the beverage
Grey water footprint	Total effluent	Litres (L)	Aspect register / Invoices	Incorporated in the beverage
Grey pollutant water footprint	Effluent load (Chemical oxygen demand (COD), Phosphates, Nitrates, Suspended Solids)	mg/litre	Effluent accounts / Aspect register	Waste water discharged through the effluent system

APPENDIX D: HSD test for production months April until August (Beverage manufacturing company data)

Total product per month	June	July	August	May
April	Sig * at 5%	Sig * at 5%	Not Sig	Not Sig
May	Sig * at 5%	Sig * at 5%	Not Sig	
August	Sig * at 5%	Not Sig		
July	Not Sig			
June				

APPENDIX E: HSD test for winter production months (Beverage manufacturing company data)

Winter months	June	July	August
May	$p < 0.01$	$p < 0.01$	Not sig
June		Not sig	$p < 0.01$
July			$p < 0.01$
August			

APPENDIX F: One-way ANOVA for summer production months (Beverage manufacturing company data)

Summer months	Sum of squares	Degree of freedom	Mean square	F	p
Between	12 078 998	7	1 725 571	0.725	0.652
Within	57 087 673	24	2 378 653		
Total	69 166 671	31			

APPENDIX G: Significant difference between sequence A and E (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: CSDPROD

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.73E+08[a]	15	18183613	20.255	.000
Intercept	1.39E+09	1	1.39E+09	1543.745	.000
YEAR	2753447.9	3	917815.96	1.022	.387
MONTH	70401814	11	6400164.9	7.129	.000
SEQUENCE	2.00E+08	1	2.00E+08	222.336	.000
Error	71818932	80	897736.65		
Total	1.73E+09	96			
Corrected Total	3.45E+08	95			

a. R Squared = .792 (Adjusted R Squared = .752)

APPENDIX H: One-way ANOVA for still beverage production (Beverage manufacturing company data)

Still beverages	Sum of squares	Degree of freedom	Mean square	F	p
Between	4 632 374	3.00	1 544 124	11.90	
Within	5 708 702	44.00	129 743		
Total	10 341 076	47.00			

APPENDIX I: One-way ANOVA between CSD production volumes and CO_2 usage for the four production years (Beverage manufacturing company data)

Years	Sum of squares	Degrees of freedom	Mean square	F	p
Between production years	0.003	3	0.001	1.609	0.201
Within production years	0.025	44	0.001		
Total	0.027	47			

APPENDIX J: One-way ANOVA between LPG usage and litres product produced for the four years (Beverage manufacturing company data).

	Sums of squares	Degrees of freedom	Means square	F	p
Between years	0.018	3	0.006	6.157	0.001
Within years	0.044	44	0.001		
Total	0.062	47			

APPENDIX K: Significant difference between electricity usage per production year (Beverage manufacturing company data)

	Sum of squares	Degrees of freedom	Mean square	F	*p*
Between years	120 638.03	3	40 212.68	4.989	0.005
Within years	354 638.63	44	8 059.97		
Total	475 276.66	47			

APPENDIX L: One-way ANOVA between production volumes and electricity usage per production year (Beverage manufacturing company data).

	Sum of squares	Degrees of freedom	Mean square	F	p
Between	0.002	3	0.001	1.63	0.196
Within	0.014	44	0.000		
Total	0.015	47			

APPENDIX M: Significant difference between treated and untreated water (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: F7

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.12E+15[a]	14	2.23E+14	2.939	.005
Intercept	7.01E+16	1	7.01E+16	923.873	.000
YEAR	5.22E+14	3	1.74E+14	2.295	.096
MONTH	2.60E+15	11	2.36E+14	3.114	.006
Error	2.50E+15	33	7.59E+13		
Total	7.57E+16	48			
Corrected Total	5.63E+15	47			

a. R Squared = .555 (Adjusted R Squared = .366)

APPENDIX N: One-way ANOVA for treated water (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: WATER

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.91E+14[a]	14	4.93E+13	6.955	.000
Intercept	1.80E+16	1	1.80E+16	2541.382	.000
YEAR	3.31E+13	3	1.10E+13	1.554	.219
MONTH	6.58E+14	11	5.98E+13	8.428	.000
Error	2.34E+14	33	7.10E+12		
Total	1.90E+16	48			
Corrected Total	9.25E+14	47			

a. R Squared = .747 (Adjusted R Squared = .639)

APPENDIX O: Two-way ANOVA between the water usage and production volumes (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: F4

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.20E+14[a]	4	7.99E+13	5.674	.001
Intercept	1.46E+16	1	1.46E+16	1039.118	.000
SEASON	2.86E+14	1	2.86E+14	20.346	.000
YEAR	3.31E+13	3	1.10E+13	.783	.510
Error	6.05E+14	43	1.41E+13		
Total	1.90E+16	48			
Corrected Total	9.25E+14	47			

a. R Squared = .345 (Adjusted R Squared = .285)

APPENDIX P: Two-way ANOVA for effluent water (Beverage manufacturing company data)

Test of Between-Subjects Effects

Dependent Variable: EFFLUENT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.67E+16[a]	15	1.11E+15	1.956	.055
Intercept	1.96E+16	1	1.96E+16	4.476	.000
YEAR	7.59E+15	4	1.90E+15	3.336	.022
MONTH	9.12E+15	11	8.29E+14	1.458	.196
Error	1.82E+16	32	5.68E+14		
Total	7.81E+16	48			
Corrected Total	3.49E+16	47			

a. R Squared = .478 (Adjusted R Squared = .234)

APPENDIX Q: Two-way ANOVA for chemical oxygen demand levels (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: COD

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.67E+08[a]	14	11952425	3.208	.003
Intercept	5.25E+08	1	5.25E+08	140.964	.000
YEAR	73843001	3	24614334	6.607	.001
MONTH	93490948	11	8499177.1	2.281	.033
Error	1.23E+08	33	3725372.7		
Total	8.15E+08	48			
Corrected Total	2.90E+08	47			

a. R Squared = .576 (Adjusted R Squared = .397)

APPENDIX R: Two-way ANOVA for phosphates levels (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: PHOS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	122.598[a]	14	8.757	1.803	.081
Intercept	170.404	1	170.404	35.085	.000
YEAR	35.559	3	11.853	2.440	.082
MONTH	87.039	11	7.913	1.629	.136
Error	160.276	33	4.857		
Total	453.278	48			
Corrected Total	282.874	47			

a. R Squared = .433 (Adjusted R Squared = .193)

APPENDIX S: Two-way ANOVA for nitrate levels (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: NITR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	18.362[a]	14	1.312	1.165	.345
Intercept	39.404	1	39.404	34.990	.000
YEAR	2.168	3	.723	.642	.594
MONTH	16.194	11	1.472	1.307	.264
Error	37.163	33	1.126		
Total	94.929	48			
Corrected Total	55.525	47			

a. R Squared = .331 (Adjusted R Squared = .047)

APPENDIX T: Two-way ANOVA for suspended solids levels (Beverage manufacturing company data)

Tests of Between-Subjects Effects

Dependent Variable: SS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	52145.458[a]	14	3724.676	.845	.619
Intercept	487428.52	1	487428.52	110.590	.000
YEAR	18925.729	3	6308.576	1.431	.251
MONTH	33219.729	11	3019.975	.685	.742
Error	145449.02	33	4407.546		
Total	685023.00	48			
Corrected Total	197594.48	47			

a. R Squared = .264 (Adjusted R Squared = -.048)