TOWARDS CARBON NEUTRALITY IN THE WINE INDUSTRY

Dissertation submitted to the Cape Wine Academy in partial fulfilment of the requirements for the Diploma of Cape Wine Master

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DECLARATION

I, Mark Wallace Philp, declare that this dissertation is my own, unaided work. It is submitted as partial fulfillment of the requirements of the Diploma of Cape Wine Master to the Cape Wine Academy. It has not been submitted before for qualification of examination in this or any other educational organization

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Signed

August 2020

ABSTRACT

This dissertation aims to achieve a greater awareness of and to disprove some false myths regarding the CO_2 generated in the pursuit of wine-making, packaging, distribution and consumption. The study examines the main factors contributing to the CO_2 emitted by the wine industry, and offers useful measures whereby CO_2 emissions may be neutralised, sequestered or eliminated. Ultimately, the research aims to serve as a tool both to increase awareness and to provide practical guidelines for producers of wine.

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1 INTRODUCTION

Global warming and the effect it has on the changing of the climate has been in the spotlight for many decades and much has been written about its impact on the planet. What, however, has effectively been done about it within the world of wine?

Sustainability is today's buzzword, but it is a complex issue. Most wine producers have tended to act as though using fewer agrochemicals in the vineyard will achieve sustainability. It's certainly a commendable practice – but it's only a start. Sustainability is based on three pillars: society (winery teams, family and its community), ecology (e.g. wine growing and making, energy, water supply, bottle weight, fertilisers), and economy. All countries and regions have different approaches, criteria and certifications and these vary based on different climatic conditions and nuances unique to those regions.

The real commitment however, is to become carbon neutral by achieving net zero carbon emissions. That is to say, balancing a measured amount of carbon released into the atmosphere with an equivalent amount of carbon sequestered and offset (zero carbon footprint). Very few producers have made a commitment to carbon neutrality, and this dissertation discusses means of measuring a carbon footprint and practical steps that can be followed in reducing a carbon footprint – with the aim of achieving carbon neutral certification. This includes investigating the best practices in the global wine industry, analysing the results from a global survey which was completed, and considering the role that wine producers and the industry as a whole can play in curbing, and being part of reversing, the global warming trend.

The main objective of this dissertation is to increase awareness among wine producers about the positive eco-impact that their viticulture and vinicultural choices can achieve. Other variables, such as supply chain requirements, changing consumer preferences and the costs of modifying current infrastructure, may influence the rate of change. However, higher awareness and the implementation of the practical steps proposed will eventually lead to a more eco-friendly industry and ultimately a greener planet.

To understand and fathom the task that lies ahead for every wine producer in their quest to achieve a reduction in their carbon footprint, it is necessary to convey the concepts that have led to the increase in carbon emissions. The background to this increase is discussed in the following chapter, in order to illustrate the effect it is having on the landscape of wine.

2 BACKGROUND

In the context of the scope of this dissertation, it is essential to understand the greenhouse concept and how gases created by humankind, which are trapped within the confines of the Earth's atmosphere, are contributing to global warming, and in turn, how this is impacting on climate change.

2.1 Greenhouse – the concept

Inbound ultraviolet (UV) radiation easily passes through the glass walls of a greenhouse and is absorbed by the plants and hard surfaces inside. These plants and surfaces then emit weaker infrared (IR) radiation, which has difficulty passing through the glass walls and is trapped inside, so warming the greenhouse and its contents. This concept lets plants flourish, even during a cold winter (Kweku et al., 2018).

As the Sun reaches the body of the Earth, some of its energy is absorbed by the ground. The weaker infrared radiation emitted by the ground is trapped by the greenhouse gas (GHG) blanket, which as a result, returns some of the heat back to Earth. Without this greenhouse effect, the average global temperature of the Earth would be significantly colder and life on Earth would be a lot less bearable.

2.2 Greenhouse gases

The Earth's atmosphere is composed primarily of nitrogen and oxygen (Sharp, 2017) These gases are transparent to incoming solar radiation and outgoing infrared radiation, meaning that they do not absorb or emit solar or infrared radiation. However, there are other gases in the Earth's atmosphere that do, and they trap infrared radiation, and these are known as the greenhouse gases. These gases trap the heat inside the Earth’s atmosphere, which gives rise to the greenhouse effect.

In a Climate Science investigation, it was found that the most common greenhouse gases that influence the Earth's climate system are: water vapour (H_2O) largely controlled by the temperature in the atmosphere; carbon dioxide (CO_2) produced by fossil fuels (coal, oil, natural gas), photosynthesis, organic decomposition and the combustion of organic material; methane (CH_4), 30 times stronger than CO_2, produced by decomposing organic plant and animal matter, cooking gas, biomass production, sewerage treatment plants, landfills and the guts of cattle and termites; nitrous oxide (N_2O), which is 294 times more damaging than CO_2, and is produced by nitrate and ammonia used in fertilisers and internal combustion engines; and ozone (O_3) produced mainly by hydrocarbons and nitrogen oxide compounds and halocarbons, composed of carbons, chlorine, fluorine and hydrogen. This includes chlorofluorocarbons (CFCs) produced by man-made gases used in refrigerators and air conditioners. CFC is 10 000 times more damaging than CO_2 (Climate Science Investigation, 2011).

Figure 1 (below) shows the effects of each of the five gases which contribute to the GHG effect (Climate Science Investigation, 2011), and Table 1 lists the lifetime of these gases.

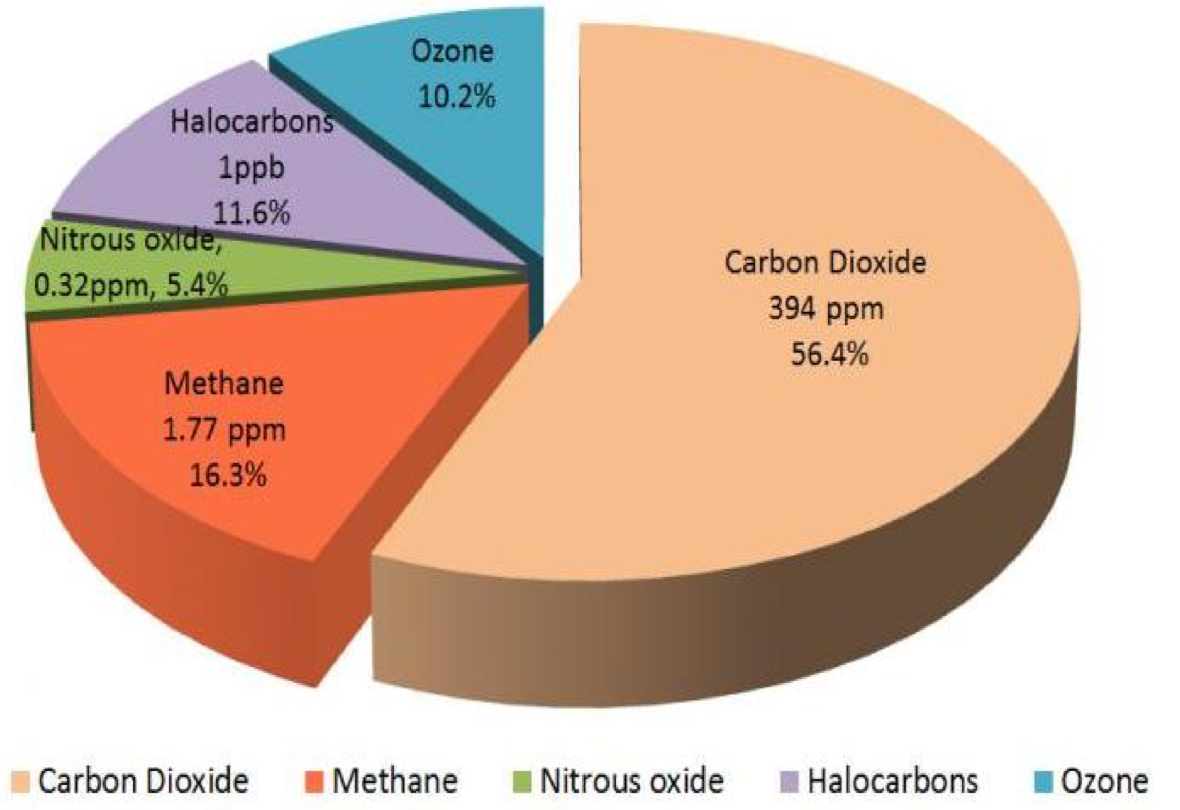

Figure 1: Greenhouse gas components (Climate Science Investigation, 2011)

Table* 1: T*he atmospheric lifetime of greenhouse gases (Moore, 2008)

GAS		ATMOSPHERIC LIFESPAN
Carbon Dioxide	CO_2	Hundreds of years
Methane	CH_4	12 years
Nitrous Oxide	N_2O	114 years
Halocarbons	CFCs	From several weeks to 50 000 years

2.3 Global warming and climate change

As a result of the ever thickening blanket of greenhouse gases in the atmosphere, the heat which is being trapped in the Earth's atmosphere causes the planet to warm up faster than at any previous time in history – resulting in climate change. Global warming drives the changes in the climate because heat is energy, and when you add any energy to a system, these changes occur. Much of the world is made up of the ocean and as the ocean heats up, more water evaporates, which results in more intensive typhoons and hurricanes leading to devastation through intensive storms, higher rainfall, and in turn, flooding. The warmer temperatures make the polar ice cap melt, raising sea levels. Changes in temperature change the wind patterns that bring snow and rain around the world, making drought and unpredictable weather more common (Warm Heart, 2017).

The most compelling evidence scientists have of climate change is long-term data relating atmospheric CO_2 levels and global temperature, sea level, the expanse of ice, the fossil record and the distribution of species (Warm Heart, 2017). These data show a strong correlation between CO_2 levels and temperature. Recent data show a trend of increasing temperature and rising CO_2 levels, beginning in the early 19th century (Warm Heart, 2017).

Professor Josef Werne, an Associate Professor at the Department of Geology and Planetary Science at the University of Pittsburgh (USA), believes that there are three options for the way forward: do nothing and live with the consequences; acclimatise to the changing climate, rising sea levels and related flooding; and/or alleviate the impact of climate change by enacting policies that actually reduce the concentration of CO_2 in the atmosphere (Dietrich School, 2019).

It is not the intention of this research to prove why the climate is changing – that has been written about for decades – but rather to discuss how it is changing and how it is affecting agriculture and, more specifically, the wine industry.

2.4 What are the world's leaders doing to curb global warming?

The Kyoto Protocol, an international agreement that aimed to reduce CO_2 emissions and the presence of greenhouse gases (GHG) in the atmosphere, was amended in Doha by the Doha Amendment in 2012 – effectively extending the agreement to 2020. It was short-lived, however, as of 2015, at the sustainable development summit held in Paris, all United Nations Framework

Convention on Climate Change (UNFCCC) participants signed yet another pact, the Paris Climate Agreement, – which effectively replaced the Kyoto Protocol.

The Paris Climate Agreement is a landmark environmental pact that was adopted by nearly every nation in 2015 to address climate change, and commitments were made from all major GHG-emitting countries to cut their climate-altering pollution – with a view to limiting the global temperature increase to a maximum of 2 degrees Celsius from 2015 until 2100.

The dialogue is still in process, but has turned into a complex issue involving politics, money, lack of leadership, lack of consensus, and bureaucracy. Today, despite many plans and some actions, comprehensive solutions to the problems of GHG emissions and global warming have not been implemented.

Initiatives from individuals and businesses, originating from the wine industry, have come to the fore – the most prominent of which is the Porto Protocol Foundation, founded by Taylors Port in Porto, Portugal (Bridge, 2019). The members are united by a commitment to make a difference in the mitigation of climate change, with the principle being to share in each other's experiences, and, in so doing, to find workable solutions.

2.5 The effect of climate change on the global wine industry

Across the globe, grape growers and winemakers are seeing the effects of climate change as temperatures rise and the changes in weather patterns become more severe.

Dr Bruce Bordelon of the Department of Horticulture and Landscape Architecture at Purdue University in Indiana (USA), notes that vineyards in hot regions of the world like Australia, Spain, Portugal, and South Africa, are particularly at risk as temperatures rise. He explains that: "changing harvest parameters and working with alternative varieties are two very big steps that these regions can take to combat the effects of climate change. Typical wine varieties tend to have high sugar and low acid as temperatures increase, so varieties that maintain some acidity could be considered 'heat-tolerant'" (Denig, 2019).

Grapevines can tolerate heat and drought and dry farming is traditionally practised in most parts of Europe. The past four years, however, have been some of the planet's hottest on record (Millar, 2018), and more warming and dryer spells are expected. On the other hand, the impact of climate change on wine production in some of the cooler European Union countries like England, Denmark, Sweden, Norway and Belgium, is generally reported to be positive (Nesbitt et al., 2016; Hannah et al., 2013) - because of the shift to a more favourable (warmer) climate for grape growing.

Climate change is real and is affecting vineyards worldwide. Winemakers must continue to make appropriate efforts to maintain environmentally friendly practices in both their vineyards and cellars, to ensure long-lasting and sustainable viticulture (Denig, 2019).

The following list contains some of the impacts that temperature rises are having on the global wine industry:

- The grape harvest is being brought forward annually. This has an effect on the quality of the wines and is changing the wine growing map (Bodegas Torres, 2018). The grapes ripen earlier, but in an unbalanced way with lower acids and tannins.
- Certain traditional cooler regions that specialise in sweeter wines, like dessert and ice wines, are making fewer vintages annually, as they are not able to pick the grapes if they are not frozen on the vine (Helmer, 2019). The temperatures have been too high at harvest time.
- Wine styles are changing as the temperature rises result in different wines being made from the same soil – vintage after vintage. The sugar, acid and tannin content affect the wine's taste and characteristics. Allan Sichel, Head of the Bordeaux Wine Council, said during Vinexpo's symposium on climate change: "Our objective is to preserve the characteristics of Bordeaux, freshness, elegance, balance, digestibility and aromatic complexity. To achieve that, we may need to change everything we do (McIntyre, 2019a).
- Additional grape varieties that are more resistant to heat, drought and disease are being sought to substitute or replace grape varieties which have traditionally been planted in specific regions. Bordeaux has responded to climate change by approving 20 additional grape varieties that will be allowed to be blended with current known grape varieties, as they struggle to achieve balance in these altered conditions. These include Touriga Naçional and Marselan (McIntyre, 2019b). Other heat-tolerant grape varieties being considered are Vermentino, Fiano, Mencia, Assyrtiko, Agiorgitiko and Tempranillo.
- As the heat builds up, sugar levels rise, resulting in higher alcohols and the concentration (wealth of fruit, richness and depth of flavour) increases changing the character of the wine. Alison Sokol Blosser of Sokol Blosser, Oregon (USA), explains: "As the heat units rise, we're going to start seeing more concentration in the wines, we're going to see higher alcohol wines, and then we may also start to see other varietals being planted that are going to grow in warmer climates" (Nigro, 2010).

2.6 Survey: What are the world's winemakers doing to curb global warming?

As part of this dissertation, a comprehensive survey questionnaire was compiled using the "Survey Monkey" web application. This was sent to 82 wine producers across the wine-making regions of the world. Appendix 7 lists all the questions in the survey. Only nine wine producers responded to the survey, of which five were certified carbon neutral, and the other four were actively practising sustainable farming methods in their businesses.

This level of response does not warrant fully presenting the results of the survey and gleaning statistics and general conclusions about the carbon footprint practices of the wine industry. The individual responses and a summary of the responses can, however, be made available to interested readers.

Despite the relatively low response, valuable insight into the carbon footprint approaches, methods, successes, obstacles and failures, was gained from the participants. In the body of text that follows, in lieu of the presentation of the results, there are many citings and references to the wineries, their owners and managers – as well as to the carbon footprint practices they adhere to.

3 CARBON EMISSIONS AND THE QUEST FOR CARBON NEUTRALITY

3.1 Carbon Emissions

Reducing agriculture's carbon footprint is central to limiting climate change. The global food system, from fertiliser manufacturing to food storage and packaging, is responsible for up to one-third of all human-caused greenhouse-gas emissions – according to the figures from the Consultative Group on International Agricultural Research (CGIAR) – a partnership of 15 research centres around the world (Gilbert, 2012).

It can be generally deduced that the agricultural sector's contribution to global warming and the resultant negative effects it has on climate change is, mostly, the emission of CO_2 gases into the atmosphere.

Carbon dioxide (CO_2) is described as a colourless gas produced by burning carbon and organic compounds and by respiration. It is naturally present in air (about 0.03 per cent), and is absorbed by plants in photosynthesis (Cryocarb, 2019).

CO_2 is released into the atmosphere when hydrocarbon fuels (i.e. wood, coal, natural gas, gasoline, and oil) are burned. During this combustion or burning, carbon from these fossil fuels combine with oxygen in the air to form CO_2 and water vapour. The primary source of CO_2 emissions is the burning of fossil fuels – most notably the burning of coal (Climate Science Investigation, 2011).

The wine industry is a significant contributor to CO_2 emissions, and thus, in order to help reverse the trend of global warming and limit climate change, which is altering both wine and wine-making, efforts should be accelerated to ensure that CO_2 emissions are curtailed and that the carbon footprint of the wine industry is radically reduced.

The wine industry can also significantly assist with the sequestration or absorption of carbon emissions.

The industry's role in both the creation of carbon emissions and carbon absorption (sequestration), in different ways, is explained below.

3.1.1 Creation of CO_2 and N_2O (Nitrous Oxide)

Ninety per cent of the world's CO_2 emissions are related to burning fossil fuels, which are mainly used in transport, heating/cooling and in most production processes. The generation of electricity, which in most developing countries relies on coal to power electricity plants, plays a large role in releasing such emissions into the atmosphere. Table 2 (below) lists the main contributions to CO_2 emissions:

Table 2*: CO_2 emissions from fossil fuel combustion (EPA, 2020)*

ACTIVITY	PRO RATA CONTRIBUTION
Electricity and Heat generation	27%
Transportation Sector	28%
Industrial Sector	22%
Residential and Commercial	12%
Agriculture	10%

Electricity for pumping water for irrigation and cleaning, running cooling and heating plants, diesel combustion for farm implements and equipment, and the transportation of goods both to and from the farm to the market-place, all play a role in the wine industry's contribution to carbon emissions into the atmosphere. In addition to CO_2 emissions, the use of synthetic nitrogen-based fertilisers results in large amounts of nitrous oxide emissions. One ton of nitrous oxide emitted into the atmosphere is equivalent to 300 tonnes of CO_2 emitted. Both these carbon and nitrous oxide emissions have a detrimental effect on the environment, and increases the carbon footprint of the wine industry.

3.1.2 Sequestration/absorption

Nature (plants and sea) can absorb or sequester CO_2, but humanity has reduced the presence of nature through deforestation to such an extent, that there is now more man-produced CO_2 than the world's carrying capacity to absorb CO_2 (IPCC, 2001). Apart from having a beneficial effect on water regulation and oxygen production, one hectare of young forest captures about 15 tons of CO_2 per year. Bamboo is especially effective and captures 62 tons of $CO_{2,}$ per hectare, per year (Van Der Zanden and De Martino, 2009). The net effect on the total absorption and creation of CO_2 explains the build-up of CO_2 in the Earth's atmosphere and the effect on our climate, our health, and the threat to the extinction of certain species.

During the grape's growing season, CO_2 is sequestered by the vines' growth and the production of sugar in the grapes during photosynthesis. This is more than the CO_2 emitted by the biomass and during the fermentation process – to such an extent that production and fermentation of 1 kg of grapes reduces the CO_2 by about 0.3 kg (Van Der Zanden and De Martino, 2009). This is known as the short-term carbon cycle.

There are, however, many other processes in each wine producing phase which have a negative effect on carbon emissions. The following chapters discuss the various factors and processes in the wine industry that have an influence on the increase of CO_2, and suggestions are made as to how to reduce the emissions of each factor, which, with sequestration examples, may lead to becoming carbon neutral.

The ultimate aim, therefore, should be to reduce the carbon footprint to a large degree by enacting sequestration principles – so that the emissions' output balances out with the sequestration of CO_2, so achieving a status known as 'Carbon Zero' or 'Carbon Neutral'.

While this study is fairly exhaustive and covers the main factors that contribute to the CO_2 and NO_2 gases emitted by the wine industry, it is incomplete due to the evolvement and implementation of new ideas that are taking place daily. It aims, however, to be a useful source of information that can increase the awareness of wine consumers and producers alike, and be a guide that may assist wine producers in their quest to achieve carbon neutrality.

3.2 Carbon Footprint

Carbon footprinting – the first step in the quest to monitor and measure reduction in carbon emissions – is calculating the total set of greenhouse gas emissions caused directly or indirectly by an individual, organisation, event or product (MET, 2020). The main reason for calculating a carbon footprint is to inform decisions on how to reduce the climate change impact of a company, service or product. Each wine-farming entity and its individual products have a unique carbon footprint – this being based on the nature of its activities and the processes that are employed in achieving the end product. In order to find a starting point in the quest to reduce carbon emissions, a measurement would have to be made of these activities and consumptions, followed by the implementation of an effective plan to reduce personal carbon footprints. The saying, 'you can't manage what you don't measure', rings true in the first step to reduce the carbon footprint. Once the size of a carbon footprint is known, a strategy can be devised to reduce it.

3.2.1 Why carbon footprinting?

Growing public awareness about climate change and global warming has resulted in an increasing interest in 'carbon footprinting'. The global community now recognises the need to reduce greenhouse gas emissions to mitigate climate change (Ahmad, 2019).

A global standard for carbon footprinting is the GHG protocol (Greenhouse Gas Protocol, 2013). It has set a global standard for how to measure, manage and report GHG emissions.

Carbon footprinting uses data already collected by a business – such as energy bills and travel expense claims – and therefore does not have to be resource-intensive. However, it is not just a tick-box exercise that improves a business's access to this all-important group participating in measuring their carbon footprint (Will, 2016).

Wine's carbon footprint pales in comparison to other consumer products or services, such as electricity generation, and even to other agricultural products such as meat and dairy, but it is still important to think about the impact that all activities have on the planet. Wine is a relatively small contributor, but that does not invalidate highlighting its role – because it helps consumers think about the fact that everything one does has a carbon footprint, even something as small as having a glass of wine.

3.2.2 Carbon footprint of a bottle of wine

Spanish company Grupo ARCE set out to get an idea of exactly what the carbon impact of a single bottle of wine was and where it came from. Following the PAS 2050 methodology (a globally accepted specification for the assessment of the life-cycle greenhouse gas emissions of goods and services), they analysed the carbon footprint of a single bottle of Verdejo, from production to consumption, and found that the average bottle of wine releases about 1.28 kilograms of carbon into the atmosphere over its life-time (Lardie, 2020).

Those wine companies and organisations that have performed a proper carbon audit on their activities have generally been surprised to learn that their biggest culprits as far as emissions go – have nothing to do with wine production. Even though CO_2 is a natural by-product of fermentation and while very few wineries capture that carbon (although the technology exists to do it), the effect thereof is nothing compared with the carbon footprint of packaging and transport (Robinson, 2020).

3.2.3 Raw material production phase emits the most carbon emissions

According to the Grupo analysis, raw materials account for 0.80 out of 1.28 kg of CO_2-equivalent emissions. This means that the analysis not only included the whole process from the grape growing to the wine-making, to drinking and throwing away of the bottle, but also included the production of the packaging and the transportation of wine – as being part of the full life-cycle of a bottle of wine. Reducing climate impacts requires a certain knowledge of how the product is made. This knowledge, together with convenient climate assessment software, as will be explained in the carbon footprint calculator below, allows a detailed analysis of which parts of the product contributes the most, and where the reduction potential is highest (Francis, 2017).

3.2.4 Scopes of carbon footprinting

Operational boundaries distinguish between direct and indirect emissions; direct emissions arise from sources owned or controlled by the business, while indirect emissions are classified as emissions that are the consequence of the activity of the business – but occur at sources owned or managed by third parties offsite (Greenhouse Gas Protocol, 2013).

To further clarify the distinction between direct and indirect emissions, the GHG Protocol (WRI, 2004) uses three different groups or scopes as subcategories (Apple, 2010).

Scope 1 emissions are termed direct emissions, as they result from activities owned and controlled by the company.

Scope 2 emissions are solely from purchased electricity, which within South Africa, is by default supplied by the state-owned utility Eskom. They are regarded as indirect emissions because they occur in equipment owned by another company (in this case, a power station).

Scope 3 emissions result from all other indirect emissions, which largely involve contracted or secondary activities.

Further clarification of the various segments in each scope are:

Scope 1 – Direct emission sources

- Transportation: Any/all fuel use for company business (e.g. stationary vineyard pumps, company owned vehicles and agricultural equipment)
- On-site waste management
- Fugitive emissions from refrigerant gas leaks
- Vineyard soil emissions (NO_2 emissions from nitrogen application)
- Change in land use – i.e. deforestation to plant new vineyards
- CO_2 used in wine-making or any other process

Scope 2 – Indirect carbon emissions

- Onsite electricity purchased from the local utility grid
- Renewable electricity generated

Scope 3 – Emissions from non-direct (supply chain) sources from the vineyard to the final disposal of the waste once the product is consumed

- Purchased products (e.g. purchased grapes, bulk wine, barrels, fertilisers, municipal water)
- Packaging materials (e.g. glass, cork, cartons, labels)
- Outsourced transportation (e.g. third party grapes, wine and finished case goods, wine barrels, bottles)
- Outsourced production (third party grape harvesting and production/bottling)
- Business travel (passenger car, train, air travel – relative to company business and daily commutes)
- Offsite waste/loss (e.g. solid waste to landfill, recycling, compost).

Figure 2 (below) illustrates the different scopes and which entities are responsible for the various activities that take place in a business:

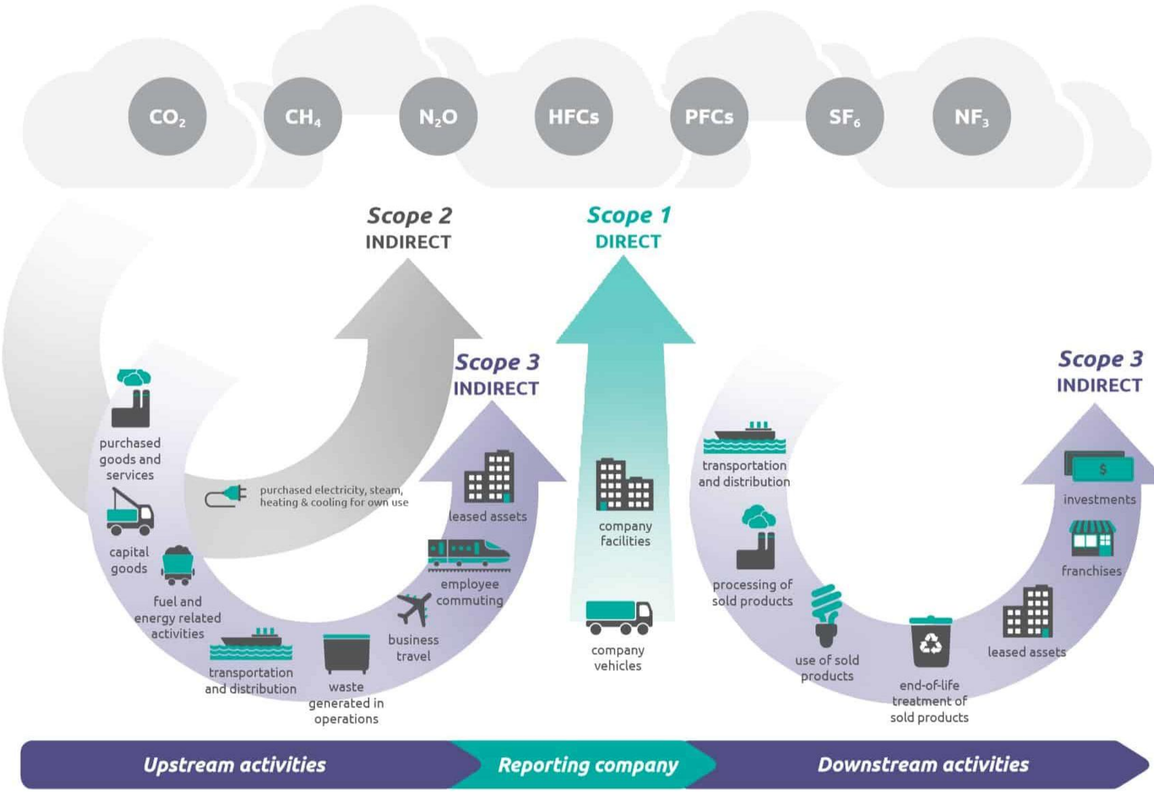

Figure 2: Carbon footprint scopes according to GHG Protocol (Greenhouse Gas Protocol, 2013)

3.2.5 Practical measurement protocol of the carbon footprint

The South African fruit and wine industry carbon calculator provides a standard protocol for the measurement and reporting of GHG emissions for the industry, and, as such, has been developed in alignment with internationally recognised greenhouse gas accounting standards such as the GHG Protocol, the ISO 14064:1, the PAS 2050:2008, the International Wine Carbon Calculator Protocol, and the recently released Australian Wine Carbon Calculator. The intention of this South African protocol document is to serve as a guide for users of the online carbon footprint tool, and to clarify the technical approach and parameters behind the GHG calculations (Apple, 2010).

The following steps pertain to the process, which is required by all wine producers when setting up a programme to reduce their carbon footprint:

1. Monitor and measure inputs.
2. Fill in the measurement tool.
3. Compare consumption with regional data.

4. Identify hotspots in the business entity.
5. Investigate ways to reduce costs and carbon footprint.
6. Manage implementation of new practices and technologies.

3.2.6 The Carbon Calculator

The 2019 Confronting Climate Change (CCC) benchmark report was established to help the South African fruit and wine industries to improve their understanding of the use of fossil fuel-based resources and to reduce emissions over time. The CCC report uses combined data from the 2011–2018 seasons to provide an industry-specific carbon dioxide equivalent (CO_2-e) benchmark. It made several key findings about carbon emissions at farm, winery and distribution level.

At farm level, the greatest contributors to the overall carbon emissions are electricity, diesel and synthetic nitrogen fertilisers. The report also confirms that in terms of packaging CO_2-e emissions, glass is by far the biggest contributor – comprising more than 80% of total emissions and averaging 0.56 kg glass per litre of white wine and 0.67 kg glass per litre of red wine.

The CCC is the only online carbon footprint calculator of its kind in South Africa, which is designed specifically for the South African fruit and wine industries.

The carbon footprint calculator:

- Helps growers identify emission hotspots and understand where to focus their efforts to reduce their carbon footprint.
- Helps growers to monitor and manage the carbon footprint with the aim of reducing emissions.
- Allows farmers to benchmark themselves against one another.
- Enables wineries to undertake accurate measurement of their energy use and carbon emissions' intensity.
- Minimises input costs and ensures greater resource-efficiency.

Anél Blignaut, Project Manager of Confronting Climate Change, states that "it is not just the right thing to do in terms of climate change, but it also makes business sense. In addition, you tick several market access boxes in terms of compliance with environmental assurance schemes" (Pretorius, 2020).

A survey which has informed the results in this paper, was done, which included global carbon neutral certified wine producers and producers who followed sustainable viticulture practices, and although the return was a low 12%, the feedback which received is shared in the relevant chapters that follow.

3.3 Scope 1 measures to reduce the carbon footprint: Direct emission sources

Achieving a sustainable energy future depends on renewable energy sources. Fossil fuels, which supply about 80% of the world's energy, will likely become depleted soon at their present rate of consumption. Biomass is projected to be a growing part of future sustainable energy sources. Biomass is a commonly used renewable energy source; it is naturally occurring, widely dispersed and although it also releases CO_2 when it is burnt for energy purposes, it is considered carbon neutral since it captures almost the same amount of CO_2 through photosynthesis during the vines growing process. This makes biomass a logical choice of raw material for the production of a broad range of fossil fuel substitutes.

3.3.1 Transportation

Fossil fuel energy sources

Diesel and other internal combustion engines convert chemical energy in the fuel into mechanical power. All fuel is a mixture of hydrocarbons, which, during an ideal combustion process, would produce only carbon dioxide (CO_2) and water vapour (H_2O). Currently, diesel is the primary source of fuel used to power farming equipment, which includes field tractors, diggers, forklifts, delivery vehicles, trucks and other heavy equipment – as total fuel costs for operating diesel engines are around 30 per cent lower than for gasoline engines. A diesel engine does not demand servicing as often as a gasoline engine, which is an important factor for any entity or process wanting optimal cost saving.

Diesel vehicles used on wine farms include field tractors, trucks, light delivery vehicles, passenger vehicles, motor cycles, quad bikes, staff buses, earth-moving equipment, frost prevention equipment, lawnmowers, generators, heating equipment, helicopters and other motorised machinery.

Vineyard maintenance consumption

In order to reduce the CO_2 emissions created by petrol and diesel with respect to vineyard maintenance, the amount of tractor hours would have to be minimised and the following remedies can be considered:

a) Performing fewer passes per row in the vineyards:
   - Applying sustainable viticulture methods.
   - Practising organic and biodynamic viticulture methods.
   - Performing two tasks simultaneously by using two tools per tractor – one in front and one in the rear.
   - Grazing of sheep, goats and chickens in the vineyards during winter.
   - Reducing soil tillage as breaking up the soil increases the biological process where organisms break down (known as decomposition) – which emits more CO_2 into the atmosphere.

b) Utilisation of electrical tractors.

c) The use of drones for crop spraying instead of tractors. Drones can carry 10 kg (10 litres) of material per time and can be programmed to return to base for refuelling when the spray mixture reaches a certain minimum level.

Other consumption – delivery vehicles, trucks, and other equipment

a) Regular maintenance ensuring optimum performance.
b) Minimising trips by ensuring better planning of farming activities.

3.3.2 On-site waste management

Biomass energy source

Biomass is defined as all plants and plant-derived materials – including feedstock such as vegetable oils, forestry residues, wastes from pulp and paper mills, urban wood wastes, woodchips, sawdust, animal manure, sewerage, plants, grains, food scraps and animal-based oils (Difference Between Science, 2020). In short, biomass can be seen as all non-fossil organic materials that have an intrinsic chemical energy content.

Forests and agricultural lands are the two largest potential biomass sources. They are inexpensive, widely available and have fewer environmental concerns than fossil fuels. The energy released from biomass is called bioenergy, which is further used for cooking, heating, lighting, and producing electricity. See more about this form of energy under Scope 2, paragraph 3.4.2.

Biomass contains stored energy from the Sun. Plants absorb the Sun's energy in a process called photosynthesis and when biomass is burned, the chemical energy in it is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels. Since biomass captures almost the same amount of CO_2 through photosynthesis while growing as is released when it is burned, this source of energy is considered to be carbon neutral.

Backsberg Estate Cellars, was, in 2006, the first carbon neutral certified winery in South Africa and the third in the world, and develops biomass energy crops and clean methane from the bio-digester which is harnessed to power converted farm vehicles and an electricity generator. In addition, the farm has installed a biomass boiler which is connected to a heat exchange chiller that allows for refrigeration and runs on waste wood chips.

Bodegas Torres in Penedes Region, Spain, has a biomass boiler which produces 2.6 MW of electricity that is used to produce steam and hot water for cleaning and which has reduced their gas consumption by 95% – preventing 1300 tons of CO_2 from entering the atmosphere per year (Bodegas Torres, 2018)

Biofuels

Fuels made from biomass resources are known as biofuels and can be used as a substitute for fossil fuels. More than half of fossil fuels are burnt in vehicles, and to reduce its usage, companies have started manufacturing vehicles that run on biofuels. Many biofuels are used in place of gasoline and diesel to run current technology and can be converted to drive equipment and transportation, which are two major requirements in the wine industry.

There are five main types of biofuel: methanol, biodiesel, butanol, ethanol, and bio-oil. They can be solid, liquid or gas (Khillar, 2019). It is common International practice to exclude biofuel combustion from the GHG emission calculation, as it is seen as a renewable source. Emissions from on-site renewable wood are negligible and are equated to zero in the calculations. Offsite wood is however calculated in the emissions' calculations. Therefore it is not advisable to truck in wood from other venues.

There are two common ways to convert plants into gas and liquid fuels (Khillar, 2019). One is to grow crops that are high in sugar (e.g. sugarcane) or starch (e.g. corn), and then use yeast to ferment ethyl alcohol (ethanol). The second is to grow plants that contain high amounts of vegetable oil – such as palm oil, soybean and algae. When these oils are heated, their viscosity is reduced, and they can be burned directly in a diesel engine, or chemically processed to produce fuels such as biodiesel. Not only is this a source of cleaner emissions, but the biodiesel can be used in biofuel engines and biodiesel-powered field tractors, further enhancing the reduction in CO_2-e emissions.

It therefore stands to reason that, in the quest to reduce CO_2 emissions on a farming unit, it is imperative to set aside waste areas for additional on-site biomass storage. This can be in the form of a compost heap on the farm and is then categorised under Scope 1, or off-site at a landfill site and is then categorised under Scope 3. All vineyard pruning and leafy waste along with grape pomace, stems and stalks should be included in the waste to bolster the biomass, which could be converted into energy and through such conversion can reduce GHG emissions in the following two ways:

- Heat and electrical energy is generated, which reduces the dependence on power plants based on fossil fuels such as coal.
- The GHG emission is significantly reduced by preventing methane emissions from decaying biomass.

The following figure depicts the sources of biomass which can be used to produce biofuels:

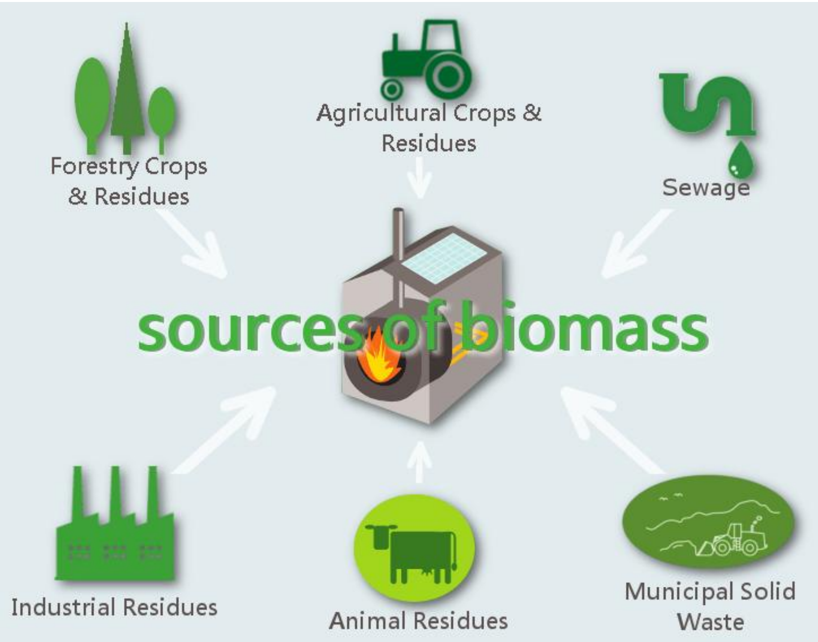

Figure 3: Sources of biomass (Zafar, 2019)

Methane digester technology

Methane digesters are systems that use anaerobes to produce methane through fermentation. The anaerobes used in methane digesters are bacteria known as methanogens. They can be found in the gastrointestinal tracts of animals such as cows and other ruminants – as well as in soil, water, and sewage.

Methane digesters are also known as biogas digesters and organic digesters. The central portion is an airtight drum called a digester unit, which contains the methanogens. Raw material is placed into the drum, and the unit is kept at a constant temperature of about 35°C. Some of the methane produced by the digester heats the water. Outlets on the digester unit take away the various products of the system. Liquid and solid fertilisers are collected to be used for crops and other plants. Methane is stored in a tank, from which it can be drawn off as fuel for a variety of purposes. CO_2 and hydrogen sulphide can be filtered out of the methane and put under pressure for use in turning turbines.

Common household organic wastes can be put into a digester, and the methane produced can be used to generate electricity. It can also be used for cooking, illumination, heating, and automobile fuel.

Methane is a clean and non-toxic automobile fuel, and produces no pollutants when burned. It has an automotive fuel octane number of 130. Italy has used it as a motor fuel for over 40 years, and Modesto, California, has a small fleet of methane-powered cars. Because of its cleanliness, it extends the life of engines, as well as making starting the engine easier.

3.3.3 Fugitive emissions

Fugitive emissions are defined as emissions of GHG that arise from leaks or spills. In the wine industry, sources such as domestic and commercial refrigeration equipment and air-conditioners, transport refrigeration, and gas insulated electrical switchboards are included (Provisor (Pty) Ltd, 2008). Refrigerator systems are run to regulate the temperature of the wine juice, in order that it has a process of controlled fermentation to stabilise the wine and for cooling purposes in pack sheds. These natural gas combustion devices are generally known to emit fugitive emissions from poor pipework connections, leaking valves, diaphragms and other miscellaneous leaks. These emissions are most likely to be limited to leaks from hydrofluorocarbon (HFC)-based refrigeration systems.

It is important to note that in some cases, the global warming potential of such CFC gases (halocarbons) are in excess of 23 000 times that of CO_2 (Provisor (Pty) Ltd, 2008).

The aim should therefore be to reduce the reliance on cooling equipment and refrigeration in the wine-making process, and to ensure regular maintenance of the cooling systems in use to avoid any leakages.

The following refrigerant groupings are believed to be the most commonly used in the South African food and wine industry:

- Refrigerant gas R-22
- Tetrafluoroethane R-134 (includes HFC 134 or 134a)
- Chlorodifluoromethane HCFC- 22
- Chlorodifluoromethane HCFC- 142b
- Chlorodifluoromethane HCFC- 152a
- Fluorocarbon R-318
- Hydrofluorocarbon HFC – 134a SF6
- Ammonia

(Apple, 2010)

In addition, energy is required to run the refrigerator systems, which, in itself, is a large source of the GHG emissions, due to the coal-powered power stations required to generate electricity.

3.3.4 Vineyard soil emissions

The proper management of vineyard soils goes a long way towards the reduction of GHG emissions, and the planting of cover crops, fertilising, tilling and irrigation practices play a large role in this regard. The application of organic materials such as manure, plant debris and compost is a direct way to improve soil carbon levels in vineyards, but it is important to note that often decades of constant management are required to make a significant difference.

Solid organic carbon is carbon that is stored in the soil and is essential for soil health and plant growth. Practices such as soil cultivation result in carbon losses, a reduction in carbon inputs, or an increase in the decomposition of soil organic matter.

The practice of soil cultivation (breaking up of the soil or tilling) and the application of fertilisers heighten carbon emissions on the vineyard floor. A two-year field study was done in Portugal in two growing seasons – between March and September 2015 and 2016 – the aim being to assess the direct N_2O emission factor between the practice of conventional tilling compared to no-tilling between the vineyard rows. The study compared no-tilling with an application of a mineral fertiliser and tilling with the same fertiliser application. It was found that there was a 60% reduction in N_2O emissions with no-tilling with the fertilizer application than tilling with the same fertilizer application. The result is that vineyard cover cropping was recommended (i.e. no-tilling) as a mitigation measure to reduce N_2O emissions (Marques et al., 2018), and at the same time, for the soil and cover crops to sequester CO_2. It must be noted that N_2O has 294 times the global warming potential than CO_2.

Soils are thus a great source of harbouring CO_2 and in viticulture, and with good land and crop management, GHG emissions can be reduced *inter alia* through adjusting methods of tilling, fertilising, harvesting, irrigation, and vineyard maintenance (more on fertilisers under *Purchased products* in Scope 3).

In a review of field studies done by the Department of Environmental Sciences and the Environmental Toxicology Program at the University of California on the effects of irrigation on GHG emissions (Sapkota et al., 2020), it was found that irrigation practices can greatly influence emissions because of their control of soil microbial activity and substrate supply. The three gases which were reported on were nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4). Within this context, the major findings from this review were that CH_4 emissions and global warming potential can be decreased by reducing irrigation water.

Proper vineyard floor management with perennial or annual cover crop species requires no tillage and thus reduced CO_2 emissions emanating from fewer tractor passes and an increased capacity for the soil to store carbon and organic matter which is protected from decomposition. There is further carbon sequestration in the growth of the cover crops and the reduction and good management of irrigation programmes can lead to a reduction in the emission of GHGs (Sapkota et al., 2020)

3.3.5 Change in land use - Deforestation to plant new vineyards

Deforestation is the permanent removal of trees to make room for expansion of agriculture and grazing – using the timber for fuel, construction or manufacturing or assigning the stripped land for residential or commercial use. This not only threatens the extinction of plants and animals, but also causes climate disruption. As vegetation absorbs CO_2, by removing natural undergrowth, shrubs and trees, that area's carbon footprint is broadened as the ability to sequester carbon from that cleared area is diminished.

According to The Food and Agriculture Organization of the United Nations (Schoene et al., 2007), deforestation is responsible for approximately 20% of global CO_2 emissions and is the second leading cause of climate change.

Within the vinicultural scenario, by changing the land use on a specific farming entity from forests to vineyards, the carbon footprint will be increased and the quest to achieve carbon neutrality will be impeded. Alternatives would need to be found to take up the carbon sequestration.

Careful consideration should therefore be given to the impact on the environment, before deciding to replace natural undergrowth with vineyards. If possible, the replacement of the uprooted vegetation by planting plants, shrubs and trees in areas within that farming unit, should be considered.

3.3.6 CO_2 used in wine-making and other processes

During the grape's growing season, CO_2 is sequestered by the vines' growth and the production of sugar in the grapes. During the fermentation process, the chemical process of converting sugar to ethanol releases CO_2. The World Resources Institute guidelines state that this CO_2 emission need not be reported in Scope 1, as it is assumed to be in balance with the vineyard sequestration. The circle is complete. This is also known as the short-term carbon cycle in the wine industry (Colman and Päster, 2009). Interestingly, the production of higher alcohol wines sequesters more CO_2 – as indicated in Table 3:

Table 3*: Alcohol content of wines versus sequestered CO_2 (Van Der Zanden and De Martino, 2009)*

AVERAGE BRIX/BALLING	CO_2 GENERATED/SEQUESTERED PER KG GRAPES
25	0.94 kg total CO_2 sequestered 0.53 kg total biomass CO_2 emission 0.1 kg produced in fermentation 0.31 kg net sequestration of CO_2
21	0.79 kg total CO_2 sequestered 0.45 kg total biomass CO_2 emission 0.1 kg produced in fermentation 0.24 kg net sequestration of CO_2

While the short-term carbon cycle has very little impact on the carbon footprint, the aim should be to find a way to capture the CO_2 generated by fermentation, to block and reuse it (which will eventually find its way back into the Earth's atmosphere) or capture and convert it into a mineral such as calcium carbonate ($CaCO_3$), which will eliminate the CO_2 forever. Both of the above will help lower a winery's carbon footprint.

Capturing of CO_2 during fermentation

The CO_2 emissions during fermentation are insignificant in comparison to the CO_2 emissions from fossil fuels, but as Miguel Torres from Bodegas Torres in Spain explains, capturing it is still a worthwhile exercise. At scale, there is a large amount of CO_2 produced and efficient ways can be found to capture it, turn it into fuel, use it to create new products, or store it as a carbonate. He goes on to say that "in this way, we will be contributing to global emission reductions by focusing on a circular economy and an innovative approach" (Torres Wines, 2016).

Algae uses up fermentation CO_2 through photosynthesis, and, from them, many products can be obtained – such as biofuels or fertilisers – or it can even be used in the treatment of waste water. The process involves feeding the captured CO_2 to photo-bioreactors, where algae grow (Torres Wines, 2016).

Bodegas Torres leads the way in research and development in carbon capture and reuse, and, ultimately, the tests they carry out are intended to show the range of possibilities offered by these technologies as a future solution for fighting climate change – particularly if they are combined (Bodegas Torres, 2018).

Bodegas Torres's environmental team has carried out tests with eight different technologies offering alternative uses of the CO_2 produced during fermentation. One of the most promising is its "Power to Gas" initiative, which sees energy generated from solar panels used to produce hydrogen, which can then be transformed into methane gas by combining it with CO_2 – using methanogenic microorganisms called Archaea as catalysers. This methane gas can then be used to power tractors as a substitute for fossil fuel. Should it be successful, not only could a winery capture and reuse its CO_2 for fuel – saving it money as well as minimising its impact on the environment – but it could also provide a winery with a secondary revenue stream, selling back unused renewable energy to the wider grid.

One of the by-products of recycling the CO_2 released during fermentation, is sodium bicarbonate (baking soda). Smith Haut Lafitte, a Bordeaux estate, produces this compound in their attempt to reduce the impact on the environment. Fabien Teitgen, Smith Haut Lafitte's technical and managing director, adds that: "if Bordeaux recycled the 55,000 tons of CO_2 released in the atmosphere during the fermentation of the annual 5.5 million hectolitres of wine the region produces, it would save the equivalent of 150 people travelling back and forth [from] Paris [to] New York every day during one year" (Marty, 2017).

The direct use of CO_2 within the winery

Carbon dioxide is a common inert gas used at wineries. Because it is denser than air, it creates a greater "blanket" when introduced into a container's head space – the outcome being that there is less chance for oxygen to enter and spoil the wine. With more blanket coverage and an inexpensive price, it is a popular choice to purchase for the best return. The use of solid CO_2 known as dry ice, is also very popular, and especially beneficial during the wine making process. Dry ice will sublime into gaseous CO_2 and maintain a blanket over grapes or must, to reduce oxygen levels. It can also keep grapes cool to prevent spontaneous fermentation. Minimum quantities of CO_2 should, however, be used to prohibit excess emissions.

3.4 Scope 2 measures to reduce the carbon footprint: Indirect emission sources

Scope 2 of the Greenhouse Gas Protocol covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the wine industry. This includes electricity purchased from the local grid and renewable electricity generated on-site.

3.4.1 Electricity purchased from the local utility grid

Coal is one of the main sources of fossil fuel energy and burning coal for energy is the greatest source of CO_2 emissions in the atmosphere. Globally, coal is the dominant electricity source accounting for approximately 40% of total electricity production through coal-powered power stations. In South Africa, the figure is approximately 88% (Stats SA, 2018). It is therefore the responsibility of every individual, household, business and farming enterprise to reduce their consumption and reliance on electricity in order to achieve a reduction in output of the coal-based power stations – with a view to reducing the impact of their CO_2 emissions.

Many of today's more progressive wineries engage in practices focused on sustainability. By implementing sustainable best practices, wineries can reduce their energy consumption and waste – which can also help reduce their carbon footprint (Henick-Kling, 2018). Wineries focussing on sustainability should aim to improve energy efficiency, water use, and waste water management, asserts Dr Thomas Henick-Kling from the Washington State University Viticulture and Oenology Program. He notes that while these efforts can be challenging for smaller wineries, they can save significant dollars and resources, so resulting in an improved bottom line (Henick-Kling, 2018).

The indirect emission sources outlined in Scope 2 refer to the direct purchase of electricity from the local utility grid. Opportunities and methods to reduce the consumption of electricity are discussed in this chapter, along with options of various renewable energy sources.

Table 4 (below) shows the typical usage of energy in a winery:

Table 4: ***Typical significant energy usage in a winery (Brent et al, 2014)***

WINERY ACTIVITY/EQUIPMENT	PRO RATA ENERGY USAGE
Refrigeration and water chiller	43%
Pumps and motors	27%
Compressors (air)	14%
Lighting	10%
Fridges and air-conditioning	3%
Cooking and kitchen	2%
Other	1%

The following viniculture and viticultural activities require electricity:

Lighting

Compared to traditional incandescent bulbs, energy-efficient light-bulbs such as halogen incandescents, compact fluorescent lamps (CFLs), and light emitting diodes (LEDs) use 25%-80% less energy and can last 3 to 25 times longer (Dept of Energy, 2018). These low energy lightbulbs can save up to 250 kg of CO_2 over a six-year period, which equates to the same as a short flight for one passenger.

The installation of motion sensors or timer switches in medium to low traffic rooms or rooms where lights are accidentally left on, like wineries, cellars, storage rooms and bathrooms, is commonly used to eliminate excess energy use. The use of overriding switches on occasions when heavy traffic is experienced and the use of outdoor motion sensors, can significantly contribute to power saving.

The installation of skylights in pack sheds to increase daylight ingress is advisable, if these do not decrease the insulation of the building, as lights can be switched off with effective daylight ingress.

Winery activities

Heating and cooling

In climates with moderate heating and cooling needs, heat pumps offer an energy-efficient alternative to furnaces and air conditioners. A standard geyser element uses 1 kilowatt (kW) of electricity to generate 1 unit of heat in the water, whereas a heat pump generates 3 to 4 units of heat with 1 kW of electricity. This implies that the owner of a heat pump will require 3 to 4 times less energy to heat water compared to the standard electrical resistance heating elements. This saving can be obtained because a heat pump uses latent heat in the air to heat the water, rather than using the electricity directly (Enerflow, 2019).

Although heat pumps have a large upfront cost, their operating costs translate to long-term savings on energy reduction in carbon emissions. Heat pumps are, however, not entirely carbon neutral as they require electricity to run – but if coupled with solar panels, heat pumps could achieve a zero net energy.

Wineries use steam to clean barrels and tanks to remove sediments and deposits. It disinfects bottles, sterilises filtering systems and filling plants, and pasteurises grape must and mash as it contains five times more energy than hot water and the density is 1000 times less, making it more efficient than any other cleansing system (Moeschle, 2019). A steam boiler consumes energy and it is vital to ensure that the operation of the equipment is of such a nature that it operates at peak performance and efficiency. Regular measurements are required to monitor the electricity consumption, and pipe insulation is of prime importance.

Pumping

Consideration should be given to modifying electrical motors to variable speed pumps and compressors. Controlling the speed of this equipment provides a decreased power factor and large energy savings. By reducing an impeller speed in a variable torque load application by 20%, energy savings of 50% can be achieved. Therefore, for most motion control applications, reducing electrical motor speed is often a very efficient way to obtain large energy savings (Control Techniques, 2020). In many instances, a typical winery pump flow rate, is in excess of what is required and just by controlling and reducing the rate , energy will be saved.

Compressed air

Many wineries depend on compressed air for powering machines for crushing and pressing of grapes, temperature control during fermentation, aeration, filtering, bottling, filling, and labelling. A program to detect leaks in the air and steam lines will contribute to energy savings.

Improvement of the insulation of piping and tanks in the winery

A temperature-controlled environment and processes are of paramount importance to the efficiency of a winery and the quality of its wine. The fermentation process itself is very temperature-sensitive, requiring storage tanks to be cooled. The primary piping system is critical to the efficient and reliable operation of the refrigeration plant, and its resultant energy saving. Insulating refrigerant supply piping to maintain a consistent processing temperature, is paramount.

Choosing the correct material for the piping system is also important for optimising performance. Often the same piping material is used for the secondary system as for the primary system. In wineries, this means that often copper or steel is used for the whole system. A plastic piping system, which is pre-insulated, can be considered, which will result in considerable energy cost savings due to the loss in cooling abilities of conventional stainless steel and copper piping.

Insulate cold rooms

It stands to reason that if cold air that is pumped into a cold room escapes, energy is lost. Proper insulation of such rooms will save the original energy which was created through the reduction of compressor usage, with the resultant saving in electricity. The insulation of wine storage tanks to reduce heat gain from surrounding air will also assist with the energy loss.

Water efficiency

It takes multiple litres of water to make one litre of wine. The water needs start in the vineyard with irrigation, but it is in the winery that the requirements thereof increase. In both of these instances, greater efficiency of water usage can be exercised to ensure that, not only is this scarce commodity protected, but, in the case of efforts to reduce carbon emissions, the act of pumping from distances can be diminished with resultant reduction in electricity consumption.

The ISO-14001 Environmental Management System (EMS) standard recommends the necessary steps for a winery towards a more environmentally friendly management of its operations. It measures and allows wineries to work towards maximizing efficiency in use of water energy, raw materials and maximizing recycling and waste treatment.

Jackson Family Wines in California have set benchmarks in water efficiency through the implementation of an internal water working group, which focuses on water reuse and the conservation thereof. Julien Gervreau, Vice President for Sustainability at Jackson Family Wines, says the company "cares about sharing best practices, taking the wins at some of the wineries and expanding them throughout the portfolio so that everybody is taking the same view of water conservation" (Danigelis, 2019). The company believes that water is critical and their ability to manage water resources was going to define their ability to succeed in the future (Danigelis, 2019). This is as a result of programmes they have embarked on to conserve both energy expended in the pumping of water and the use of a precious resource.

Water usage in the vineyard

a) Irrigation

Irrigation impacts on the carbon footprint of winery business units, not only because of the energy used to pump water from its source to the end usage, but also because of the greater release of nitrous oxide (N_2O) from anaerobic soil conditions such as waterlogged or compacted soils – as discussed in previous chapters.

Irrigation is also a topic that raises many questions in terms of sustainability. Dryland versus irrigated farming practices? Is vine irrigation a sustainable practice in viticulture? Should irrigation be acceptable for sustainable, organic and biodynamic viticulture? These are not questions that can be answered in the scope of this study. However, suffice to say, water requirements for dry farming are small and thus the energy requirements are negligible.

Different irrigation methods have different water consumption requirements – the most frugal of the methods being drip irrigation, which increases efficiency of water usage in the vineyard by up to 90%, compared to, for example, flood irrigation.

The reuse of treated wastewater is an effective way to conserve water, but the energy required to treat and pump the water to the end usage is sometimes high. The practice of recycling water used in the winery for cleaning and the use of captured water from rainwater harvesting for irrigating vineyards, are efficient practices due to the reduced pumping requirements to bring water from long distances.

b) Mulching

Mulch is a layer of material consisting of dead leaves, twigs, grass clippings, hay, straw, branches, animal manure, compost and other plant debris, which is placed on the surface of the soil and helps to enrich and improve the structure of the soil and retain moisture and coolness – so reducing evaporation and therefore irrigation and pumping energy needs. Optimum soil temperatures and less moisture evaporation from the soil surface helps plants to grow evenly.

c) Biochar

Biochar is a charcoal-like substance made by burning biomass through a controlled process called pyrolysis. With the effective application of biochar into the soil, the plant growth of the soil is enhanced and it minimises water usage by increasing the water storage capacity. The reduction in irrigation needs therefore has a direct influence on the need to supply energy to pump water from source to the vineyard. Biochar and its carbon sequestering properties are discussed in more depth in paragraph 4.3.2.

Water usage in the winery

Wineries generate significant amounts of wastewater, mostly stemming from the cleaning and sanitising processes. The water requirement in the winery is often overlooked and is therefore not tracked or managed effectively. Jackson Family Wines based in California, USA, has created one of the benchmarks on the water savings front, through various initiatives that have been successfully implemented. They track the water usage at their wineries over time, observing trends and comparing the current usage with that of the past, and use the results to institute incentives for their management to reduce consumption. Their water conservation efforts include recycling and reusing tank wash water for irrigation, increased cycles of concentration on cooling towers, vineyard drip irrigation systems and weather-driven irrigation practices, and innovative sap-flow monitoring technology and rainwater harvesting – which have led to a 41% reduction in their water usage (Jackson Family Wines, 2016).

If the source of the water is above ground with gravity feed possible to the winery, internal design of the processes in the winery should be such that electricity is not required to move water through the winery.

The capturing of rainwater or water harvesting from roofs of buildings is a common practice and the saving in required energy to pump such water for the short distance – as opposed to conventional longer distances to the winery – is significant.

The following functions in the winery require water for effective operations:

a) Cleaning

Cleaning of equipment and facilities before and after crushing, destemming and pressing is essential to ensure that there is no bacterial growth that can affect the quality of the wine from grape to the bottle. The cleaning process of tanks, barrels, pumps, filters and bottling equipment is a further requirement before and after use. This is imperative to ensure good hygiene throughout the process.

Hot water from washing of bottles and barrels can be reused to clean equipment, and Jackson Family Wines have pioneered UV technology to sanitise their tanks using just UV lights at the end of harvest (Mustacich, 2019).

Steaming of barrels to remove bacteria and yeast is common practice, as the water vapour can penetrate up to 8 mm into a wooden stave. The use of steam generators can save up to 75% in water usage, and while energy is required to fire the boilers or generators, biomass can be used as an acceptable source of energy for this purpose. Jackson Family Wines has commissioned an automated barrel washing line that is fitted with water recycling units, which capture barrel wash water for use three times over (Jackson Family Wines, 2016).

b) Cooling

In addition to pumping the water for cleaning purposes, water is also used to maintain temperature control over the wine, so contributing to the energy requirements.

Jackson Family Wines have installed cooling towers for their barrel rooms and by controlling the fan speeds, they can control the amount of water leaving the cooling unit. These units are installed outside of the wineries and run the refrigeration systems that cool the barrel halls. The settings and cycles of concentration are adjusted so that the systems recycle more water – in some instances between 4 and 6 times over. Captured rainwater is used, which is stored in fermentation tanks in winter, and they achieve a large reduction in their water consumption as a result.

c) Wastewater treatment

Wastewater treatment contributes significantly to improving the environmental impact of winery operations. There are extreme levels of suspended solids in wastewater and industrial treatment and screening technologies are available to effectively capture and remove these – preventing them from overloading treatment processes and enabling wineries to recycle the organic material. While it is necessary for each winery to have some form of recycling practice it does have a negative effect on the energy consumption, which includes the treating of the water to get it to acceptable standards. Finding efficient ways to solve such operational problems will significantly increase any winery's environmental sustainability.

Facility space

The effective insulation of winery, storage and pack-house buildings and cellars can eliminate the excessive use of cooling plants to ensure optimum temperatures – thereby reducing the energy requirements to operate these plants.

In the design or redesigning of facilities, small windows and doors will help with such insulation and underground cellars to keep the temperatures constant and will contribute significantly to reducing energy requirements.

3.4.2 On-site renewable electricity generated

Renewable energy comes from natural sources or processes that are constantly replenished, examples of which are sunlight or wind. These are sources of energy that are alternative to the most commonly used non-sustainable sources like coal. The use of renewable energy will continue to increase into the future, edging out fossil fuels and reducing greenhouse gas emissions, and is important in reducing air pollution and expanding energy access.

The most common renewable energy sources used in the wine industry are solar, wind and biomass energy.

Solar energy

Solar energy is the energy the Earth receives from the Sun, primarily as visible light and other forms of electromagnetic radiation. Photovoltaics (PV) is the field of technology and research related to the application of solar cells for energy production, by converting Sun energy directly into electricity (Energypedia, 2018). The implementation of solar energy systems in wineries is gathering momentum, with the acceptance that, going solar, the carbon footprint is reduced due to the reduction in demand for fossil fuels.

One such winery is Vrede-en-Lust in Franschhoek, South Africa. "Our wines are vinified by the Sun," says winemaker Susan Erasmus (Vrede en Lust, 2016). "We looked at a more sustainable approach to the winery's energy needs, and so we installed a 220 kVA system. We operate off the grid during daylight hours and during the first year we cut our carbon footprint in half."

The head of family-owned Spanish wine business Familia Torres, Miguel Torres, has often spoken of his desire to make Bodegas Torres run entirely on renewable energy, above all, using power generated from the Sun. "PV panels are the energy of the future, solar energy is a must," he stated (Schmitt, 2017). Currently, 25% of the energy consumption of Familia Torres winery operations comes from renewable self-energy resources, which includes solar.

Wind energy

Wind is a plentiful source of clean energy and is making an ever-increasing contribution to national grids around the world. In California, at Scheid family wines, they have erected a domestic turbine system to harness electricity to run their winery and bottling operation (Randall, 2018). Not every property is suitable for domestic wind turbines due to the lack of a constant source of wind and the costs related to the implementation of such a project – which could be inhibitive for operational viability.

Biomass energy

This is the conversion of solid fuel made up of plant materials into electricity, as has been partially discussed under 3.4.2. The following methods can be implemented for the harnessing of such energy:

Collecting the winter pruning and pomace (grape skins and seeds from the winery presses), drying them under cover, chipping and burning them in ovens/biomass boilers attached to the winery is an alternative source of energy to fossil fuels to create heating, cooling and electricity – thus reducing the carbon footprint of the winery operation. Disposing of such waste and transporting it to an off-site landfill, leads to increased fossil fuel usage which would have a negative impact on the carbon footprint.

Familia Torres uses biomass boilers, which at the start of operation produced 2.6 MW for generation of steam and heating water for cleaning, and allowed them to reduce gas consumption by 95% (Torres Wines, 2016).

Methane digester technology

Grapes generate different wastes such as pomace (skins, seeds and stalks), lees and other residues, and if combined with animal waste/manure, sewerage and food scraps, by anaerobic digestion (creating an environment devoid of oxygen thus fully submerged in water) – produces energy in the form of methane. Methane digesters control the decomposition of the aforementioned mixture and convert the resultant methane emissions into biogas, an alternative fuel, and a nutrient-rich fertiliser – see Figure 4.

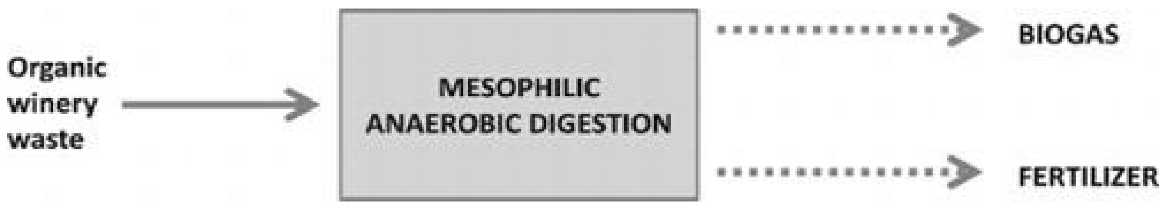

Figure 4: Biogas and fertiliser production from fermentation of winery waste (Hungria et al, 2020)

The digester holds this mixture in an air-tight tank and heats it to about 100 degrees – similar to a cow's stomach. Bacteria in the manure thrive in these conditions and they consume solids in the manure while releasing methane gas. The excess heat from the generator warms the digester.

Due to the high content of methane in biogas (typically 50-75%), the biogas is flammable, producing a deep blue flame that can be used as an energy source. Biogas alleviates two major environmental problems: the global waste epidemic that releases dangerous levels of methane gas and the reliance on fossil fuel energy to meet global energy demand. Biogas can be used as gas, electricity, for heat/cooking and for transportation fuels.

A highly productive by-product of anaerobic digestion is fertiliser. As the organic material decomposes in a liquid environment, nutrients present in the waste dissolve into the water and create a nutrient-rich sludge that is used as fertiliser.

It is therefore clear that significant reductions in energy consumption can be made in both the vineyard and the winery to reduce the reliance on purchasing electricity from the local grid and so reduce the footprint, which also includes large cost savings.

3.5 Scope 3 measures to reduce the carbon footprint: Indirect emission sources excluding electricity from the grid

Scope 3 of the Greenhouse Gas Protocol includes all other indirect emissions that occur in the wine value chain – excluding generated or purchased electricity as discussed under Scope 2.

These include all purchased products, packaging materials, outsourced transportation and production, business travel, and off-site waste practices.

This section will continue to highlight the sections that require carbon footprint measurement and will offer ideas and suggestions to reduce carbon emissions in the quest to achieve carbon neutrality.

3.5.1 Purchased products

Fertilisers and pesticides

Fertilisers are chemical or natural substances applied to the crops to increase their fertility and productivity. In viticulture they are used to increase the grape yield in the vineyard, as they contain the essential nutrients required by the plants – including nitrogen, potassium and phosphorus.

Synthetic fertilisers contain nutrient elements made by chemical means for the growth of crops. Nitrogen improves the production and quality of the vineyard, whereas phosphorus stimulates root growth. Organic fertilisers, on the other hand, are natural – in that the nutrients they possess are strictly comprised of plant- or animal-based materials and they enrich the soil with carbonic compounds that promote growth.

Both these types of fertiliser serve a purpose based on the vines' needs. If they need food fast, inorganic may be preferable. If the interest is more a long-term nutrient solution, organic would be the preferred option. The two, however, have vastly different impacts on the environment.

The contribution of fertiliser to greenhouse gases comes mainly from nitrogen (Fertiliser Association, 2018). In applying fertiliser nitrogen to soil results in nitrous oxide (N_2O) emissions, because of the natural biological soil processes that take place (Fertiliser Association, 2018). These emissions result from nitrates applied to the soil from synthetic fertilisers that are in excess of the plant's requirements. Thus, if the application occurs at the wrong time, at the wrong place, and in excess of the plant requirements, then excess N_2O emissions will result. For example, applying nitrogen during excessively wet periods significantly increases the release of N_2O into the atmosphere. When soil is in this condition nitrogen is lost to the atmosphere as N_2O, and is not available to the vine. N_2O emissions are an indication of wasted nitrogen fertiliser and reducing these emissions can improve economic and production efficiency.

Organic fertilisers (solids and liquid) or composts are an environmentally sound investment in viticulture sustainability (Mowbot Team, 2018). They are created from the by-products of naturally occurring processes i.e. nature itself. Even though they take longer to work, organic fertilisers provide a healthy food source for vines at a fraction of the N_2O emissions emitted by synthetic fertilisers (Nganchamung et al., 2017). In the context of this study, it stands to reason that in order to reduce the carbon footprint and to achieve carbon neutrality – the healthier environmental alternative to choose is the organic fertiliser.

Yealands Estate Wines, a carbon neutral winery business in Marlborough, New Zealand, has a composting programme that addresses an industry-wide landfill problem. Working beyond their vineyard boundaries they have a partnership with aquaculture and forestry industries which has driven compost production to more than 50 000 tons per year, so benefitting the wider Marlborough region (Sustainable Business Network, 2014). They have committed to further reducing their carbon emissions by 50% by 2030, and by 80% by 2045 (Hart, 2020).

The reduction of emissions of N_2O from fertiliser and compost can be effected in the following ways:

- Fertiliser management – the right source, rate, time, and place.
- Reducing the use of synthetic nitrogen fertiliser.

- Using appropriate manure management practices.
- Using appropriate crop rotations.
- Using cover crops.
- Developing and using a comprehensive nutrient management plan.

(Woodbury and Wightman, 2018)

Pesticides (herbicides, fungicides and insecticides) can contaminate soil, water, plants and other vegetation – in addition to killing insects and weeds that grow and live in the vineyards.

Fertilisers and pesticides pollute the local environment, with the result that some wine producers are moving to more organic and biodynamic wine-growing practices that have a minimum impact on the environment. The absence of artificial fertilisers, chemicals, pesticides and genetically modified materials, generally leads to lower soil emissions of N_2O.

The focus of this dissertation is on carbon neutrality and methods used to reduce the carbon footprint. It does not, however, examine different viticulture practices. It would, however, be remiss if there was not a short section of organic and biodynamic practices, as these viticultural approaches embody several of the methods suggested in this study to minimise impact on the environment.

Organic viticulture

Viticultural practices in organic farming centre on the protection and improvement of the soil. Growers implement organic farming practices to build soil organic matter (compost applications and cover crops) and employ pest management solutions compatible with organic farming practices. In all instances, the use of synthetic fertilisers and pesticides are prohibited – which results in a reduction of carbon emissions and the carbon footprint.

Conversely, the reduction in the carbon footprint is impeded as more tractor passes are required to tend to the principles of organic viticulture. Soils need to be tilled for weed control, and more frequent spraying of organic solutions (copper sulphate) is required to protect the vines from disease, mildew and fungi. Conventional farming methods spray herbicides once in the season, but in that time kill off the entire ecosystem – both insects and animals – which the organic producer attempts to protect.

Bertie Coetzee from Lowerland Farm in the Northern Cape, South Africa, explains their approach: “We follow a hands-off approach in our certified organic vineyards. Mulching and allowing natural succession to do its thing has seen a cover crop of native grasses return to nourish and protect the soil from the harsh Northern Cape Sun" (Lowerland, 2020)

There is much debate globally about whether organic wine-making practices produce more or less CO_2 than conventional farming methods, and whether they have more benefit to the environment. While more carbon is sequestered in the soil with organic farming methods, the tilling needs of such farming practices and programmes could result in an increase in emissions.

Adrian Bridge, the CEO of Fladgate Partnership, owners of Taylors Port, is not a proponent of organic farming, as he claims this practice is a less efficient form of farming and that it requires a greater use of copper sulphate in the treatment of mildew in the vines. He claims that it is better to be a sustainable farmer that minimises the use of herbicides, and cuts down on pesticides, without having to remove them altogether (Schmitt, 2019).

Miguel Torres from Familia Torres in Spain, and climate change activist in the wine industry, states that there is an increased amount of energy required for organic farming and also cites the use of copper as being negative due to its toxicity levels (Schmitt, 2019). He explains: "because copper is less effective than synthetic chemicals against fungal diseases such as mildew, it needs to be applied more often, which in turn produces more carbon emissions from the greater number of miles travelled by the vehicles spraying the heavy metal." He goes on to say that "with organics there are more emissions because we have to pass through the vineyard more often" (Schmitt, 2019) .

Biodynamic viticulture

Organic and biodynamic viticulture are very similar in that they both farm without the use of artificial fertilisers or synthetic chemicals. Biodynamic farming however goes one step further. It is a holistic practice where all things are considered living interrelated systems – animals, plants and the solar system, and also incorporates astrological influences.

In brief, biodynamic viticulture deals with, and does not manipulate nature. Biodynamic farmers rely on balanced growth, they react on the soil, use composting chips, manure from stables and cows, pomace, work with the resources available and react to what they observe, as opposed to 'second guessing'. They follow the natural rhythms of the earth, sun and moon, and, as an example, believe that, as the moon moves closer to the earth, all energy goes to the roots of the vine and the process of pruning and planting takes place and as it ascends, all energy concentrates on the plants above the ground when spraying and harvesting takes place. (Collins, 2020).

The results of an environmental impact study performed in the viticulture of biodynamic and conventional viticulture practices in North West Spain, showed there was a significant reduction in the overall environmental and carbon footprint impacts with biodynamic relative to conventional viticulture methods (Villanueva-Rey et al., 2013).

3.5.2 Packaging materials

Packaging vessel

Grupo ARCE, a company that has expertise in calculating carbon footprints, analysed the carbon footprint (CF) of a single bottle of Verdejo wine from Rueda, Spain. Table 5 (below) shows the make-up of the CF of a bottle of wine, which equals 1,2144 kg of CO_2 – the largest slice of the impact stemming from packaging.

Table 5*: Carbon emission share of Spanish Verdejo wine (Buehner, 2012)*

WINE PRODUCTION PROCESS	CARBON EMISSION SHARE
Packaging	46%
Grape production	32%
Energy	16%
Waste disposal	3%
Refrigerant gas	3%

From Table 5 it is clear that packaging contributes almost half of the CF of a bottle of wine. The study goes on to estimate that 85% of that packaging portion of the CF is contributed by glass.

Table 6*: Packaging processes as a percent of total packaging carbon footprint (Buehner, 2012)*

PACKAGING PROCESS	SHARE OF PACKAGING CF
Glass	85%
Cardboard	9%
Labels	1%
Cork	4%
Bottle caps	1%

Therefore, 39% of the CF of a bottle of wine is contributed by the glass bottle alone.

Figure 5: Glass contribution to wine carbon footprint (Buehner, 2012)

In a similar study, the California Association of Wine Grape Growers published a comprehensive California Code of Sustainable Winegrowing Self-Assessment Workbook, which indicated that the impacts from packaging were due to the energy requirements of producing the requisite materials – such as the glass bottle and the corrugated box. Closures had a relatively small impact, ranging from 1–3%. They found that packaging design decisions had the ability to significantly reduce a winery's footprint. For example, light weighting of glass bottles would lead to significant reductions in environmental burden (Carbon Footprint: California Wine Study, 2010).

Below are a range of holding vessels and their negative and positive impacts on the carbon footprint in the wine industry.

Glass

One of the best ways to reduce the carbon footprint of glass is by opting for lighter bottles or finding alternative vessels in which to house the wine. The current technical lower limit of 330 g for 750 ml still wine bottles, saves 15% of the total carbon footprint compared to standard 500 g bottles, including the savings on transport emissions. Conversely, a premium 750 g bottle can increase the carbon footprint by 20% (Pretorius, 2020).

In the 7000 year history of wine, amphorae, jars, skins and barrels were the vessels of choice. It was not until 250 years ago that glass was found to be an acceptable replacement. In the 17th century came the onion shape, and was replaced in the 19th century by the Bordeaux and Burgundy bottle shapes. It has been mooted that the wine industry needs a 21st century wine bottle. Wine traded and re-traded several times should be traded in a wine bottle due to its ageing properties, but an alternative to glass is called for – especially for the wine destined for immediate consumption. The English journalist and wine writer Andrew Jefford states, "All that is really needed is some kind of light, short-term container to get wine from the local supermarket to the consumer's wine glass at home. Every other stage of the journey could be accomplished in a bulk container with a much smaller carbon footprint than glass. Not only is it less expensive but [it] plays a large role in the reduction of the carbon footprint" (Jefford, 2018).

Is it the industry or is it the consumer which says that wine should be presented in a glass bottle? There is something mystifying and romantic about wine being served from a bottle, but perceptions are changing. Younger consumers are more receptive to other packaging types that are better for the environment.

If glass packaging is one of the largest contributors to the carbon footprint in the wine industry, then finding alternatives is the way forward and should be accelerated.

Euromonitor International's research in July 2019 showed that 80% of all table wine in the UK sold for £5.50 a bottle or less. Therefore, the wines are cheap and an alternative lightweight packaging would go a long way in bringing the price down further – while having a major impact on the carbon footprint of wine in the global market. Conversely, 80% of wines sold on the Chinese market are above the equivalent of £10, due to expensive tastes.

Wine bottle glass is recyclable and this can be done without a loss in quality or purity, but, as the bottles come in so many different colour shades of green and brown, they need to be sorted by colour by the recycling plant to match the colour standards required. This is a prohibiting factor which is one of the reasons why so many bottles go unrecycled. The recycling rate of glass varies from country to country, largely due to the lack of instituted and applied recycling programmes. The US Environmental

Protection Agency has reported that only 28% of glass in America gets recycled (Hubble, 2016). This is in contrast to the UK at approximately 50% and the Netherlands – where it is claimed that 90% of glass gets recycled. Waste recycling programmes for glass should be implemented or scaled up globally and financial and other incentives should be put in place to create awareness of the importance of recycling. Using recycled glass means less mining for new materials, less energy usage, and thereby fewer carbon emissions. Every 6 tons of glass recycled saves 1 ton of carbon from being released into the atmosphere.

PET plastic bottles - polyethylene terephthalate

An alternative to glass packaging and a product which is finding a fair amount of traction in the market place is PET – a plastic wine bottle made from polyethylene terephthalate.

PET is 87% lighter than glass in weight (which reduces the transportation carbon footprint) and accounts for 77% less greenhouse gas emissions. PET does not have the same oxygen barrier properties that glass has, and therefore the potential ageing of wine in this vessel is impeded. The CO_2 emissions of recycled PET were also found to be 79% lower than for the production of new PET bottles.

Garçon Wines in the UK has developed a ground-breaking, almost-flat, letterbox-friendly, 750 ml wine bottle made from 100 per cent recyclable PET, which has an oxygen scavenger inside it. This gives the wine a shelf life of 12 to 18 months, roughly the same – according to former Accolade Wine chief winemaker Barry Dick (Master of Wine) – as a bag-in-box package. Dick cautions: “I would not recommend ageing a wine in the postable PET bottle” (Jefford, 2018). The design and lightness of the bottle poses problems for existing bottling lines, although Dick managed to produce conventionally shaped PET bottles for Sainsburys, and is confident these problems can be overcome. Plastic may be recyclable, but it’s not biodegradable in the way that an ideal container would be (Jefford, 2018).

A Best Foot Forward Ltd report from Australia considered a comparison between using Amcor-designed PET bottles versus typical glass bottles used by UK-based bottlers, and found that glass bottles have a higher recycled content than PET, and that existing systems for glass recycling are more sophisticated than for PET recycling – so additional carbon savings are obtained for glass when end-of-life impacts are considered (The Best Foot Forward, 2008).

Glass producers say that the end consumer will decide whether the wine should be presented in a glass bottle or not. There is, however, no data supporting the fact that consumers are looking for a heavy bottle. Some argue that high-end buyers place value in a heavy bottle, while others think it an unfounded opinion. For the new generation of wine drinkers to decide, they would need to be informed about every aspect of the transformation. The question remains – who should the environmentalists educate and who is giving the most resistance to alternative packaging? The consumer or the wine producers?

For the sake of reducing carbon footprint, it could be argued that it is paramount to take the weight out of the glass bottle and to find alternative vessels, in order to settle the question, sooner rather than later.

Cans

The evolution of wine in cans as an alternative packaging to bottles is here, and has taken off in the US where more than 600 individual canned wine products have entered the market in the last 10 years. According to Nielsen data reported in *Wine & Spirits Daily*, canned wine sales in America increased 69% during 2018 (Weed, 2019). The rest of the world is following suit, and while there are many reasons for the increase in popularity with consumers, this paper only reflects on the environmental impact cans have with respect to carbon emissions as an alternative packaging to glass.

The advantages to the environment are that aluminium cans are lighter than glass, which means there is less energy required to transport the product to the marketplace and they take up less space, enabling greater volume to be transported. This results in a reduction of carbon emissions with respect to freight per litre of wine.

One drawback of cans is that aluminium is extracted from bauxite ore. Other than the fact that this mining is destructive to the environment, the smelting process is energy intensive – thus having a negative impact in terms of increased carbon emissions. Roughly speaking, it takes nearly 15 times the amount of energy to produce new aluminium than it does to produce new glass.

Recycling aluminium on the other hand conserves significant amounts of energy, by reducing the impact of bauxite mining and the energy production required for smelting. Only 5% of the energy needed to produce new aluminium is needed to recycle old aluminium back into new aluminium. The ability to infinitely recycle aluminium cans is a further advantage to the environment, as opposed to hindrances and the reduction in glass quality when undergoing the glass recycling process.

Stand up Pouch (SUP), Bag in Box (BIB) and carton

Stand up Pouches (SUP), bag in box (BIB) and cartons are three similar wine packaging products that offer an alternative to glass bottles as storage for wine. These are produced in various shapes and sizes, with their production make-up consisting of polyethylene (the most popular plastic used in the world), aluminium and cardboard – which all require a lot less energy to produce than glass. Both the cardboard and the plastic bags the wine is stored in, are recyclable and their light weight and space efficiency make transport easier, resulting in a reduction in the carbon footprint.

Table 7 (below), with permission of Gaia Consulting Oy, indicates the comparison of the global warming potential of packaging for glass, PET, Bag in Box, Stand up Pouch and cartons, based on an 'Update on wine packaging' report completed in 2018.

The results show that the global warming potential of PET is 40% of that of glass, 11% of BIBs, 14% of SUPs and 13% of cartons.

Kegs

The keg wine or wine on tap dispensing systems are providing a good alternative to glass bottles for on-consumption sales locations, such as hotels, bars and restaurants – as they have been found to be very effective in the distribution of wine-by-the-glass offerings. These kegs are cleanable, recyclable stainless-steel cylinders equipped with piped inert gas to keep the wine fresh. A 10 litre keg holds more than a 13 x 750 ml bottles, saving on carbon emissions from transport and bottle manufacturing, and the empty kegs are returned for cleaning and refilling. Kegs can be cleaned and reused many times and some companies are making recyclable kegs in an attempt to close the waste loop.

Closures

The environmental impact of packaging is becoming an increasingly important factor in closure selection among winemakers. The impact of wine closures is, however, relatively small on carbon emissions, in comparison to the larger items of the packaging process.

Amorim, the world's largest natural cork producer, were commissioned Ernst & Young to do a Lifestyle Assessment study on the impact of cork production on carbon emissions, and its effect on the environment. The results of the study – which was published in April 2020 – showed that natural cork captures 309 g of CO_2 for still wine and 562 g for sparkling wine and can therefore offset the carbon emission of other elements of the production chain such as bottles (Turner, 2020).

Table 7: Global warming potential of packaging alternatives (Päällysaho et al., 2018)

IMPACT CATEGORY	UNIT	TOTAL
750 ml PET bottle produced in France		
Abiotic resources depletion potential	kg Sb eq.	0.00024
Water consumption	m^3	0.85
Primary energy	MJ Primary	6061
Global warming potential	kg CO_2 eq.	**243**
750 ml Glass Bottle produced in France		
Abiotic resources depletion potential	kg Sb eq.	0.00041
Water consumption	m^3	3.99
Primary energy	MJ Primary	11280
Global warming potential	kg CO_2 eq.	**609**
3 Litre Bag in Box produced in France		
Abiotic resources depletion potential	kg Sb eq.	0.00002
Water consumption	m^3	0.95
Primary energy	MJ Primary	2256
Global warming potential	kg CO_2 eq.	**69**
1.5 Litre Stand Up Pouch produced in France		
Abiotic resources depletion potential	kg Sb eq.	0.00002
Water consumption	m^3	0.27
Primary energy	MJ Primary	2938
Global warming potential	kg CO_2 eq.	**88**
1 Litre Beverage carton produced in Netherlands		
Abiotic resources depletion potential	kg Sb eq.	0
Water consumption	m^3	0.6
Primary energy	MJ Primary	3011
Global warming potential	kg CO_2 eq.	**76.4**

A UK-based company, Nomacorc, has created the first carbon neutral, fully recyclable wine cork made from a biopolymer derived from sugarcane ("Braskem Europe," n.d.). Its claim is that the stopper has a net zero impact on the environment. However, it still does not come close to that of natural cork with the Ernst and Young study showing the net CO_2 capturing ability of natural cork. Other forms of closures like synthetic, agglomerated cork (small pieces of natural cork stuck together with glue) and aluminium screwcaps (the mining and refining of aluminium used to make screwcaps is energy intensive), release up to 25 times more carbon – so the emission savings in natural cork in comparison to its counterparts is significant. A further benefit to the environment of natural cork is that it is biodegradable and fully recyclable (Turner, 2020).

Cartons

It is claimed by Tony Hitchin, General Manager of Pro Carton, that cartons are one of the eco-friendliest forms of packaging. In a partnership with Pro Carton, the European Association of Carton and Carton Board Manufacturers and the Research Institute of Sweden, have carried out an extensive research project that found that for every ton of carton manufactured by the carton packaging industry in Europe, only 326 kg of CO_2 is emitted. This figure takes into account every aspect of the manufacturing process, including all emissions from fossil fuels, as well as those from renewable sources such as plants and trees, plus removals and emissions from direct land-use change (The Two Sides Team, 2020).

Cartons have a recycling rate of 85% (Eurostat), 56% of the primary energy used being biomass-based, 82% of raw materials are sourced from responsibly managed forests, and 95% of the water used is cleaned and reused (Midland Paper, 2020).

Pallets

The use of pallets in the wine industry is universal and the materials used vary from wood, plastic, cardboard to wood-polymer composites.

In a February 2020 research paper released by a group of Penn State researchers, it is declared that pallets made of wood are slightly more environmentally friendly and sustainable than those made of plastic. They investigated and evaluated the environmental impact of resources consumed and emissions released by wooden and plastic pallets throughout their life cycles (Penn State, 2020).

Plastic pallets have a much longer life cycle than wooden pallets, as they are made of sturdy hardened material and are built to last longer. They are, however, made from petroleum or natural gas products, which greatly increases their carbon footprint.

According to the Penn State research team, after conducting a series of detailed comparisons, it was found that the pallets made of wood are slightly more environmentally friendly and sustainable than those made of plastic (Penn State, 2020).

A further factor to consider is that wood is replaceable, 100% recyclable, biodegradable, and is a renewable energy source. Plastic is not biodegradable and is a non-renewable source.

3.5.3 Outsourced transportation

Most CO_2 emitted into the atmosphere in the wine industry is caused by transport and the choice of packaging. The two go hand in hand. This section focuses on the transportation of wine from its source to the market place and the ways in which it impacts the reduction of the carbon footprint in the quest to achieve carbon neutrality.

Modes of shipping methods

The wine industry can reduce its footprint significantly by finding alternative transportation methods to move lightweight or bulk material from source to the end destination.

Transportation GHG emissions are often given relative to the weight of the goods and the distances they are transported – providing a reasonable way of estimating emissions when all that is known is weight, mode, and distance.

Colman and Päster published a study of different transportation methods of moving wine around the world and found that air cargo is the worst, and shipping by sea the most efficient method - five times less polluting than trucking and eleven times less than air cargo. That means that if you live on the east coast of the United States, California wine received via air transport will have a larger carbon footprint than French wine sent via cargo ship from Bordeaux (Colman and Päster, 2009).

Table 8 shows levels of CO_2 generated per ton and km for various modes of transport:

***Table 8*: CO_2 emissions of transport alternatives (Colman and Päster, 2009)**

TRANSPORT MODE	g CO_2 / Ton km	g CO_2 / Bottle km *	g CO_2 / Bottle km **
Air	570 g	0.76 g	0.45 g
Ship (standard)	52 g	0.07 g	0.04 g
Ship (refrigerated)	67 g	0.09 g	0.05 g
Road	252 g	0.34 g	0.20 g

* based on 6 meter container carrying 12000 light-weight (375 g) glass bottles

** based on 6 meter container carrying 24000 litres bulk in flexitanks.

It is therefore imperative to choose the correct mode of transport in the movement of wine, in order to reduce the carbon footprint of the wine producer.

Shipping in bulk

Shipping wine in bulk packaging (flexitanks allowing zero oxygen permeability) and bottling it close to destination can save 35-50% in transport CO_2 – thus greatly reducing emissions. A container of bulk wine holds two and half times as much wine as a container packed with conventional 750 ml bottles. The technology of bulk shipping of wine has improved significantly in the last few years, as has the expertise of professional wine bottlers in major wine-importing countries in northern Europe, resulting in much more consistent wine, with much lower levels of harmful oxygen than the bottling equipment typically used in a producer's cellar (Robinson, 2020). As much as 45% of all still wine (sparkling wine has to be transported in bottle) imported into the UK arrives in bulk (Robinson, 2020).

Flexitanks, the most common used bulk container for wine transportation, are recyclable and are sent to be recycled once used – ensuring little contribution to waste.

In South Africa, the majority of wine is produced in the Western Cape, the most southern part of the country – but most consumers are far north and east of that. Transporting in bulk and bottling at destination will reduce carbon emissions and the carbon footprint.

3.5.4 Outsourced production and on-site machinery

In the production of purchased grapes, must or wine (if the winery controls the production system of the purchased grapes or must), the emissions created by these third parties or suppliers in the course of their viticulture and viniculture practices may not be known to the purchasing winery. In cases like these, in the process of measuring the carbon footprint, a representative emission coefficient should be used.

Fuel used by machinery leased from outside contractors that has been employed in the viticulture and viniculture operations (e.g. tractors, harvesters, forklifts) also needs to be tracked to ensure an accurate assessment of the business unit's total carbon footprint.

3.5.5 Business travel

All road and air travel (domestic and international) for business activities needs to be taken into account and the need to reduce these are imperative in the reduction of the carbon footprint through effective planning and the questioning of the requirement of such travel. The impact which the recent pandemic, COVID-19, will have on the carbon footprint is enormous, as producers have gravitated to communication via electronic means by conducting business meetings online.

3.5.6 Waste disposal – off-site

The transportation of waste items to the municipal waste/landfill site has a negative effect on the carbon footprint due to the carbon emissions derived from the transportation itself. The more effective a recycling programme, the less transportation of such waste to the landfill site, and the smaller the carbon footprint.

All the by-products stemming from the viniculture and viticulture activities can be utilised on-site in some form or another through effective recycling programmes – whether it be pruned canes, grape pomace or unused packaging materials. Many of the factors discussed in previous chapters have touched on recycling ideas which, if implemented, will reduce the carbon footprint considerably.

The following are examples of benchmarks on the waste management front:

- Chateau St Jean Winery in Sonoma Valley reuses or recycles virtually all waste products from the vineyard, wine-making and bottling processes. In addition to savings from the reduced number of dumpsters required for waste, St Jean now can realise rebates for scrap tin, cardboard, glass and some plastic packaging (Weber and Bahner, 1999).
- Buena Vista Winery Inc. in Sonoma has, in order to reduce the amount of cardboard which needs to be recycled, worked closely with their suppliers to produce boxes that can be shipped back to them for reuse. They also have an ongoing employee education programme that

highlights current and new recycling policies. Their waste reduction and recycling programme has decreased the use of additional general waste containers from two to one (Weber and Bahner, 1999).

- Fetzer Vineyards in California reduced its waste by 94%. The company recycles or reuses 13.5 tons of plastic shrink wrap, 70 tons of corrugated cardboard, 75 cubic yards of paper board, 10,000 cases of glass, 740 gallons of oil, and 392 cubic yards of wooden pallets. They also compost 12 cubic yards of corks and 10,000 tons of grape seeds per year (Weber and Bahner, 1999).
- Korbel Champagne Cellars in California recycles waste oils, solvents, paints, laboratory processing chemicals, and metals. More than 500 tons of cardboard per year are baled and sold. All glass, shrink wrap and shipping plastics are also recycled. Over a six-year period, Korbel has been able to reduce refuse to landfill costs by 50 per cent (Weber and Bahner, 1999).

Packaging materials can be an expensive disposal problem for wineries. Recycling these materials can help reduce that cost, as well as conserve energy (Weber and Bahner, 1999).

4 CARBON NEUTRAL CERTIFICATION

4.1 Carbon neutral – the concept

Carbon neutrality can be defined as achieving net zero carbon emissions by balancing a measured amount of carbon released (carbon footprint) with an equivalent amount of carbon sequestered or offset. Such an offset can be achieved by companies by investing in environmental projects around the world in order to balance out their own carbon footprints through the following guidelines:

- ISO 14064
- PAS 2050
- Greenhouse Gas (GHG) Protocol.

Backsberg Estate Cellars became the first carbon neutral winery in South Africa, a wine-producing country that could be seriously affected by climate change in the next 20 years. In 2006, Backsberg was only the third winery in the world to achieve such a certification. In an interview with Michael Back, owner of Backsberg (Appendix B), discussions took place on the steps taken to reach carbon neutrality, including *inter alia*, the tree planting initiatives on the farm and in the nearby town of Klapmuts, the use of biofuels to offset excess carbon, the manufacture and application of biochar, the process of mulching followed, and also the transportation on and off the farm which has a large impact on the carbon footprint of the business unit. Michael Back received the Green Lifetime Achievement Award In 2015 for his contribution to the environment, sustainability, ethical practices and education (Ridley, 2015). Michael is renowned for challenging conventions in terms of environmental action and sustainability, and is also well respected for his community work and passion for social responsibility. "Care for the environment means care and concern for succeeding generations. As custodians of the land, it is our duty to understand and recognise potential threats, and to mitigate against them for the benefit of the next generation," says Back (Backsberg, 2006). His forward-thinking has already rescued several plant species from extinction by reserving 10% of his land for non-development and preservation of the endangered "Fynbos" biome. He also stressed that every business decision should bear in mind the effect of such a decision on the environment. He added that: “It has to be wired into the DNA of the business to ensure that the whole team thinks and acts along the same lines".

Firriato, a Sicilian winery which has been supporting active environmental policies for over a decade, is among the world’s few wine cellars to be certified carbon neutral. The COO of the company, Federico Lombardo, says: “It is a result that puts us at the forefront of those who want to affirm with the facts a productive path of environmental sustainability with a commitment on the front line” (Terenghi, 2019).

Tinhorn Creek Vineyards became Canada's first carbon-neutral winery, following New Zealand's first, Grove Mill Winery, and California's Parducci Winery. General Manager of Tinhorn Creek, Shaun Everest, says that they were “prepped for the move to carbon-neutral status by engaging with the Climate Smart program offered by Ecotrust Canada” (Tinhorn Creek, 2020). Everest told Wines & Vines that "Climate Smart was a framework that helped us understand the whole process" (Tinhorn Creek, 2020).

Fetzer Vineyards in California, USA, became a carbon neutral winery in partnership with Natural Capital Partners, with the certification spanning greenhouse gas emissions of the company’s operations. Giancarlo Bianchetti, CEO of Fetzer Vineyards, says: “Fetzer Vineyards are working to implement a regenerative strategy to operate ways that restore, revitalise and regenerate ecosystems and communities, while producing premium quality wines, advancing the wealth and well-being of employees and producing sustainable growth for its shareholders” (Fetzer Wines, 2017). The company believes that they need to make a positive impact to sustain the world (Fetzer Wines, 2017).

As mentioned in the introduction chapter, to achieve carbon neutrality the following steps need to be followed, as proposed by Natural Capital Partners in a carbon neutral protocol document published in 2018 (Natural Capital Partners, 2018):

1. Define what should be covered in your footprint.
2. Measure your carbon footprint by calculating it accurately and conservatively. By mapping the energy usage, an understanding and awareness will be created.
3. Set a target to achieve carbon neutrality by drawing up a plan to reduce energy consumption, including the generation of renewable energy. Suggestions have been made in previous chapters and are listed in a forthcoming chapter.
4. Offset the CO_2 emissions which cannot be eliminated through financing projects that deliver verified emission reductions. First reduce what you can, and then offset the remainder.

5. Communicate completed steps with stakeholders – customers, employees, suppliers and shareholders – and inspire others to follow your lead. An effective communication strategy will help you to position your unique product and business in your market place.

4.2 Reasons for and benefits in achieving carbon neutrality

The reasons for and benefits in achieving carbon neutrality, can be summarised as follows:

4.2.1 The climate change problem

In the background chapter to this dissertation, it was made clear that the warming of the Earth in the last 50 years is attributable to human-emitted greenhouse gases, and the resultant effects of climate change will lead to significant and widespread risks as the Earth's temperature rises even further. Several studies suggest that climate change poses stark risks for vineyards, which may be exposed to more extreme weather and see traditional grape varieties struggle to achieve balance in altered conditions. Many scientists believe that it is close to inevitable that global temperatures will rise by two degrees this century – without rapid and decisive intervention from the world's biggest polluters. Increasing temperatures will mean that the grape harvest is earlier every year, which could affect the quality of wines and even alter the vine growing map of the world.

4.2.2 Cost

Both carbon neutral producers and those that follow sustainable farming practices have, in the survey that was sent out (see Appendix A), cited that the financial burden which is placed on a business unit to achieve carbon neutral certification, is a stumbling block due to the large capital outlays in infrastructure and equipment needed to reduce the carbon footprint.

There can, however, conversely be a large saving of energy costs through self-generation of sustainable energy and by applying the aforementioned measures to reduce the farming unit's consumption of energy in a smart and cost-effective manner.

Businesses should also mitigate the risk that possible future governmental regulations may include taxes on carbon consumption.

4.2.3 Marketing

A sustainable business leads to more customer loyalty, a more effective purchase intention, the attraction of valuable employees with increased morale, and it creates goodwill and a good reputation among all stakeholders (Carbon Footprint Management.com, 2020).

Moreover, the disposable income of the millennial generation is on the rise and due to their changing preferences, wines with better sustainability credentials are gaining a greater competitive advantage over those with less sustainable practices.

An exploratory study of Italian consumers to assess the millennial consumer interest in wines with proven environmental, social and ethical attributes, showed a significant increase in the probability of buying sustainable wine (Pomarici and Vecchio, 2014). Carbon neutral wines fall within this category. There is no doubt that a marketing opportunity awaits those wineries who follow the sustainability route and efforts should be increased to meet rising consumer demand for sustainable or environmentally-friendly wines. In this context, there is an opportunity for increased revenue by differentiating oneself in the wine market-place.

4.2.4 Global fossil energy sources

The assumption can be made that the supply of fossil fuels will be exhausted at some time in the future and therefore more efficiency in energy consumption and investments in the generation of renewable energy will lead to certainty of future energy supply.

4.3 Negative CO_2 emissions or sequestration

The removal of CO_2 or creating negative emissions is to permanently remove and store CO_2 from the atmosphere. Reforestation, or the large-scale planting of trees and the thermal decomposition of biomass to form charcoal (biochar), which keeps carbon in the soil, are two ways of attempting to reach negative emissions.

4.3.1 Biodiversity

Forests are one of the most important ecosystems on Earth due to plants' ability to capture CO_2 from the atmosphere and transform it into biomass through photosynthesis. Sequestered carbon is then accumulated in the form of biomass, deadwood, and litter in forest soils. Deforestation, i.e. cutting down trees in a large area to make way for farming and cattle grazing of commercial developments, is one of the leading causes of climate change, and it is thus critical to protect forests to mitigate such climate change.

Reforestation, i.e. the planting of trees and the growing of hedges to demarcate the individual vineyard lots on owned land, sequesters atmospheric CO_2 and has therefore become common practice in the offsetting of CO_2. It is, however, difficult to practice biodiversity in certain parts of the world in regions where land is expensive and every inch is required to be planted with vines to ensure financial viability – for example in Burgundy, France.

All of the respondents of the survey, which was conducted, have tree planting programmes. Vergelegen from Somerset West, South Africa, have an ongoing programme of uprooting alien vegetation and replacing it with 50 000 trees on the 2500 ha they have set aside for a reserve and national park.

4.3.2 Biochar

Biochar is produced by heating biomass in the absence of oxygen. When biomass is subjected to this pyrolysis process, the majority of carbon remains in the solid product, which helps to reduce the amount of CO_2 emitted into the atmosphere, and at the same time enhances plant growth through nutrition retention and minimises the water usage by increasing the water storage capacity of the soil.

Biochar stores its own carbon, but also sequesters additional carbon as it draws more CO_2 from the air as soil conditions improve (Russan, 2020).

4.3.3 Capturing methane gas at landfill sites

Municipal landfill sites produce gases (methane and carbon dioxide) which are released when anaerobic bacteria decompose organic waste – the formation of which lasts from about 6 months after arriving at the site, for a period of about 20 years. These gases can be captured and converted into an energy source suitable for generating electricity or as a combustible fuel.

This method of capturing gas on landfill sites and the conversion thereof is a way of carbon-offsetting that will generate carbon credits in the carbon footprint measurement.

4.3.4 Capturing CO_2 in the fermentation process

Bodegas Torres leads the way in research and development in carbon capture and reuse, and ultimately, the tests that they carry out are intended to show the range of possibilities offered by these technologies as a future solution for fighting climate change – particularly if they are combined (Bodegas Torres, 2018). The capturing of CO_2 in the fermentation process was dealt with under section 3.3.6.

The results from the survey conducted indicated that while 50% of the respondents measure the CO_2 emissions from the fermentation process,, none of them captures and transfers the emissions in order to achieve a credit on their carbon footprint.

4.3.5 Following natural viticulture practices

Pruned biomass (dead vines, thinning shoots, leaves and canes), when incorporated in the soil, is a source of carbon sequestration. It is therefore advised that all of the vine parts be chipped and incorporated into soil as organic matter. Plant cover crops like cereals and grasses sowed in the vineyard rows will also increase soil carbon storage.

4.4 Carbon offsets

4.4.1 Background

Carbon offset programmes allow wineries to invest in environmental projects around the world in order to bridge the gap between their carbon footprint score (net carbon emissions) and the achievement of carbon neutrality. The projects are usually based in developing countries and most commonly are designed to reduce future emissions. An example of an offsetting programme is that of Oregon wineries in the USA. They have focussed on regional projects to purchase their offsets from, to make it more meaningful to them and their customers. One such project is the state's largest dairy farm, which works on collecting methane waste from cows and converting it into biogas. "For us, it was important to find one or two projects that can be linked directly back to us", according to Mat Elmore, the program associate for the Oregon Carbon Neutral Challenge, which consists of 14 wineries representing 20% of Oregon's wine production attempting to reduce their environmental impact (Nigro, 2010). This allows tasting-room and sales staff to explain the programme more easily to their customers. Elmore adds: "A lot of people are sceptical about offsets. We wanted wineries to be able to tell their consumers they can go a couple of hundred miles and they could see this and it's supporting farmers. We wanted to be able to have some close accountability" (Nigro, 2010).

The concluding step in the certification of carbon neutrality and thus achieving the zero emissions point for Firriato Winery in Sicily, was through the purchase of certified carbon credits. These supported specific environmental protection activities in emerging economies that resulted in reforestation projects in tropical areas and the production of energy from renewable sources (Terenghi, 2019).

Tinhorn Creek Vineyards, Canada's first carbon-neutral winery, supports conservation projects in the South Okanagan Valley, but is not willing to sell carbon credits (Tinhorn Creek, 2020). This is something that Chile's De Martino Winery began doing this year (2020), after investing $1.5 million in carbon reducing technologies (Van Der Zanden and De Martino, 2009).

Fetzer Vineyards in California also support external emission reduction projects around the world after having maximised their internal efficiencies. These include capturing methane from landfill sites, delivering reforestation in North America, and supporting wind energy projects in India (Fetzer Wines, 2017).

CO_2 offset projects come in various forms, and below are a few examples of project types where contributions can be made:

- Wind energy projects.
- Small-scale biogas projects – installing equipment to convert landfill gas and animal waste into energy.

- Distributing efficient cooking stoves – helping poor families save money on fuel and improve their household air quality.
- Distribution of low-energy lightbulbs in developing countries, thereby reducing energy consumption.
- Education grants.

4.4.2 Cost of purchasing carbon credits

There are many ways to value a carbon credit, and although it is a complex issue, the basic guidelines to follow when considering the purchase of carbon credits are pricing using market dynamics (supply and demand), the project's size and cost, the value that the project delivers, and the project's type and quality.

Different project types provide different levels of benefits. The Gold Standard which sets the standard for climate and development interventions illustrates the point by comparing a wind project with a cook stove project. The wind project provides country-level benefits such as better access to clean technologies, local employment opportunities, energy independence and increased social stability – whereas an improved cook stove project based in a developing country benefits people at a community level. It decreases indoor air pollution, improving health predominantly among women and children. Less wood is required, helping to decrease deforestation and saving families money, and less time is needed for collecting wood, so providing more opportunities for schooling and social activities. Although the sustainable development benefits delivered by wind projects are also important, often carbon credits from cook stove projects will sell at a higher price (Gold Standard, 2019).

The answer to the question of how much one should pay for a carbon credit is, however, very complex, and considering the aforementioned comparison can be very subjective. Many companies globally market carbon credits and prices vary considerably.

4.4.3 Is buying carbon credits controversial?

Offsetting by means of buying carbon credits is sometimes seen as controversial, especially if it takes the place of internal efforts at first reducing emissions through behaviour or operational change. It can also be perceived as being an easy way to shift the burden of action away from those who are more affluent.

If, however, maximum feasible efforts have been made by wineries to reduce their carbon footprint by successfully achieving the goals and reaching the targets of a reduction programme, then the buying of offset credits to help reduce poverty in the developing world, for example, can only benefit the global cause of reaching carbon neutrality.

4.5 Obstacles in achieving carbon neutrality

The respondents in the survey (Appendix A) conducted indicated that the following stumbling blocks exist and would need to be overcome in the quest to achieve carbon neutrality:

- Financial requirements in investment in infrastructure and equipment are too stringent.
- Shortage of time and personnel to manage and monitor the process.
- Carbon Neutrality is poorly understood in the beginning, without clear guidelines to follow.
- There is a resistance to change.

Eighty-three per cent of the respondents overcame the hurdles once the concepts had been explained and understood by their business team members, with staff engagement programmes which implemented aimed at imprinting the principles in the DNA of their businesses. Yealands in the Marlborough Region, New Zealand, have funds allocated to implement sustainability ideas submitted by staff, and have developed a dashboard as a live carbon tracker for their teams to see the impact from *inter alia* their air travel and freight options. The dashboard includes clear emission reduction targets and strategies. In addition to this, Yealands responded in the survey that they provide biodiversity funding for non-profit groups in the community, support local businesses who also align with their sustainability goals, and partner with universities undertaking research to increase efficiencies in reducing carbon emissions.

5 CONCLUSIONS AND PRACTICAL MEASURES TO ACHIEVE CARBON NEUTRALITY

5.1 The quest for carbon neutrality

To gain carbon neutral certification, is to achieve net zero carbon emissions by balancing the carbon emitted into the atmosphere with the equivalent amount of carbon sequestered, which may include the purchasing of carbon offsets for the carbon measurement which cannot be reduced any further. To track progress in the attempts to further reduce carbon emissions, an accurate measurement and update of a carbon footprint is required.

While wine is a relatively eco-friendly product, the international wine trade is making a sizeable contribution to humanity's greenhouse gas emissions, with each bottle currently generating an estimated 1.2 kg of CO_2 during its lifetime (Buehner, 2012). The contribution made to the carbon footprint by the wine industry is consistently communicated to the consumer with the result that buying habits are changing resulting in more the purchase of more eco-friendly alternatives. Due to the increase in millennials' disposable income and their changing preferences, those products which have large sustainable credentials will have a greater marketing and revenue generating advantage.

For a winery to mitigate the consequences of global warming, making viticulture adjustments by moving towards using the right rootstock, drought-resistant grape varieties, planning the planting spacing, and restricting irrigation, is just the start. The long-term solution is for the wine industry to play its role in curbing the increase in temperature by aiming to achieve carbon neutrality by adopting measures, as researched in this dissertation. The following list of measures to reduce the carbon footprint acts as a useful guideline for producers, acknowledging that it is by no means exhaustive, and, through time, and with new technologies and collective ideas, it is likely to be expanded.

5.2 Summary of measures to reduce the carbon footprint leading to carbon neutrality

5.2.1 Scope 1 – Direct carbon emissions

- Transportation:
  - Reduce tractor and farm vehicle size.
  - Plan fewer tractor passes per row through practising more sustainable viticulture methods.
  - Perform two tasks simultaneously per tractor pass – one in front of the tractor and the other in the rear.
  - Use electrical tractors.
  - Use electrical or hybrid vehicles for the farm and employee use
  - Use drones for spraying.
  - Change vineyard layout to reduce tractor mileage.
  - Use electrical forklifts.
  - Regularly maintain equipment to ensure optimum performance.
- On-site waste management:
  - Embrace alternative energy sources from biomass.
  - Develop biomass energy crops.
  - Collect all non-fossil organic materials and convert them into biomass to create biofuel and biogas through a biogas digester system.
  - Install a biomass boiler to produce heat, steam, and if exchanged, refrigeration.
- Fugitive emissions:
  - Reduce the use of refrigeration in the wine-making process
  - Ensure regular maintenance of the cooling systems to avoid leakages.
- Vineyard soil emissions:
  - Practise effective vineyard floor management by planting cover crops that require no tillage of the soil.
  - Good management of irrigation programmes to reduce excess irrigation to control soil microbial activity.
- Change in land usage:
  - Avoid the replacement of natural undergrowth with vineyards.
  - Replace uprooted vegetation elsewhere on the farming unit.

- CO_2 used in wine-making and other processes:
  - Install efficient plumbed CO_2 lines for wine storage to minimise CO_2 usage.
  - Pick grapes at lower Brix/balling.
  - Capture CO_2 in the fermentation process.
  - Refrain from using dry-ice or additional CO_2 application to protect musts and juices from oxygen.

5.2.2 Scope 2 – Indirect carbon emissions

- Electricity purchased from local utility grid:
  - Reduce energy usage.
  - Upgrade lights to highly efficient LEDs.
  - Shut off lights and office equipment when not in use.
  - Install motion sensors and timers for lighting.
  - Install day/night sensors for lighting.
  - Install skylights to increase daylight ingress.
  - Track energy usage for employees to encourage changing behaviour.
  - Upgrade to more efficient refrigeration systems.
  - Reconfigure winery cooling and fermentation control.
  - Modify electrical motors to variable speed motors.
  - Use of cooling equipment in the evenings, when ambient temperatures are cooler.
  - Improve the insulation of piping and winery cooling equipment.
  - Insulate cold rooms.
  - Re-use hot water used for sterilisation in bottling for other activities that require hot water, like cleaning operations.
  - Use heat pumps.
  - Provide incentives and ongoing training for management and employees on water conservation.
  - Install a reservoir system for waste water.
  - Use waste water for the first rinse of tanks.
  - Save rinse water from the final rinse of tanks for reuse.
  - Use UV technology to sanitise tanks after harvest.
  - Return unused wastewater to parks and gardens.
  - Do preventative maintenance on tanks.

    - Document all clean-up procedures, which include water conservation methods.
    - Use high pressure and low volume cleaning equipment.
    - Using mops and buckets rather than hoses for floor cleaning.
    - Add building insulation by reducing air leaks through window and door frames.
    - Monitor water usage monthly – unusual water usage can be an indication of maintenance needs.
    - Do regular checks for and repair all leaks.
    - Install irrigation processes and fittings that improve water-use efficiency.
    - Maintain irrigation systems and repair defective lines and sprinkler heads.
    - Adjust sprinklers for effective coverage.
    - Adjust irrigation times and durations according to seasons.
    - Use mulch under vines to maximise water retention – thus saving water.
- On-site renewable electricity generated:
    - Embark on a solar power project to replace the purchase of electricity from the local utility grid.
    - Practise on-site waste management for biomass, biogas and biofuels.

5.2.3 Scope 3 – Indirect carbon emissions (excluding electricity from the grid)

- Purchased products
    - Use only organic fertilisers.
    - Reduce hazardous material usage such as synthetic fertilisers.
    - Reduce the use of pesticides.
    - Introduce an ecosystem in the vineyards that will harbour insects and other animals in order to protect the vines from pests – thus reducing the use of pesticides.
    - Grow winter cover crops that fix carbon and nitrogen in the soil.
    - Implement sheep grazing between vine rows after harvest to reduce tractor hours, weeds and fertiliser usage.
    - Use mulch under vines to maximise water retention.
    - Introduce biochar in the vineyard to maximise water retention and nutrition.
- Packaging materials:
    - Reduce the average weight of the glass bottle used.
    - Minimise rejects from the bottling line.
    - Use alternative vessels to glass.

  - Change plastics to biodegradable or recycling alternatives.
  - Maximise paper, cardboard and plastic recycling.
  - Use wooden pallets over plastic ones.
- Outsourced transportation:
  - Consider cheaper modes of shipping.
  - Consider contracting electrical trucks for overland transportation of goods
  - Consider bulk shipments and the concept of bottling at destination.
- Outsourced production:
  - Localising production – use only your own grapes.
- Business travel:
  - Plan local and international trips effectively to reduce transport emissions.
- Off-site waste/loss:
  - Reduce the quantity of off-site waste.
  - Implement an on-site waste management programme to replace what is being transported off-site.

APPENDIX A – QUESTIONNAIRE SURVEY TO WINE FARMERS

Survey sent to 82 Carbon Neutral and Sustainable Wine Producers in South Africa and Globally during March to July 2020

General Survey Questions:

Q1

Basic Details

- First Name
- Last Name
- Email Address

Q2

Producer Name

Q3

Please indicate your location

- Country

Q4

Please insert your region, i.e. Overberg, Bordeaux or Sonoma.

Q5

Do you support sustainable viticultural practices?

- Yes
- No

Q6

Are you certified in the following viticultural practices?

- Organic
- Biodynamic
- None

Q7

Is your business entity certified as Carbon Neutral?

- Yes
- No

Carbon Neutral Certified Questions:

Q8

What, for you, are the largest stumbling blocks to achieving carbon neutrality?

- Financial
- Time and the lack thereof
- Lack of knowledge of what it entailed
- Too complicated
- Excessive paperwork
- Poorly understood
- Resistance to change
- Did not believe that it was necessary

Q9

In tracking your carbon footprint, which practices do you subscribe to?

- Solar power
- Wind power
- Capture methane gas at landfill sites
- Practice methane digester technology
- Manage organic waste
- Have waste areas set aside for additional biomass
- Converting biomass into biofuel
- Partake in a programme in supplying biomass to a renewable energy manufacturing plant
- Equipment with biofuel engines
- Have a tree-planting project
- Produce and apply biochar
- Have electric field tractors

Q10

Which of these packaging processes do you use?

- Glass bottles
- Cans
- PET bottle
- Bag-in-Box
- Tetrapak
- Stand Up Pouch (SUP)
- Bev Carton Elopak

Q11

What is the average weight of the glass bottle which you use?

- 300-350 g
- 350-400 g
- 400-450 g
- >450 g

Q12

Do you use drones for spraying?

- Yes
- No

Q13

Do you set aside a portion of your land with the objective of re-greening – Planting of vegetation - Biodiversity - establishing natural vegetation to offset carbon use?

- Yes
- No

Q14

If so, approximately what percentage of your total land is non-developed?

- 10%
- 20%
- 30%
- 40%
- 50%
- >50%

Q15

Do you measure the CO_2 emitted from the wine production during the fermentation process?

- Yes
- No

Q16

Do you sequester CO2 from the fermentation process?

- Yes
- No

Q17

Do you irrigate your established vineyards?

- Yes
- No

Q18

Do you have a rainwater capturing programme – rainwater harvesting?

- Yes
- No

Q19

Which recycling programme do you have?

- Water/waste water
- Paper/cardboard
- Plastic

Q20

Do you purchase carbon credits/offsets to achieve Carbon Neutral certification?

- Yes
- No

Q21

What portion of the total carbon usage are you not able to achieve before having to purchase offsets to gain neutrality?

Q22

What mode of transport do you use to transport your wine domestically?

- Road
- Rail
- Sea
- Air

Q23

What mode of transport do you use for exporting your wine?

- Road
- Rail
- Sea
- Air
- We do not export

Q24

In your distribution process do you bottle any wines closer to its eventual destination, the buying market?

- Yes
- No

Q25

Do you have an active Social Responsibility Programme?

- Yes
- No

Q26

What other initiatives do you exercise in reducing your carbon footprint to maintain carbon neutral certification?

Q27

Do you have any further comments, suggestions or ideas which will assist in the research of the topic, 'Carbon Neutrality in the Wine Industry?'

Sustainable Wine Farming Questions:

Q28

Do you track the carbon usage of your business practice?

- Yes
- No

Q29

Do you track carbon emissions for:

- Scope 1
- Scope 2
- Scope 3

Q30

Do you have a plan/desire in place to track the carbon usage for the next Scope?

- Yes
- No
- Not applicable

Q31

Is the tracking of carbon usage of the next Scope attainable for your organisation?

- Yes
- No
- Not applicable

Q32

If not, what are the problem areas?

- Too expensive
- Shortage of time

- Poorly understood - lack of knowledge of what it entails
- Too complicated
- Excessive paperwork
- Resistance to change
- Don't believe that it is necessary

Q33

What, in your mind, are the largest stumbling blocks to achieving carbon neutrality?

- Financial
- Shortage of time
- Poorly understood – lack of knowledge of what it entails
- Too complicated
- Excessive paperwork
- Resistance to change
- Don't believe that it is necessary

Q34

To which practices do you subscribe to reduce your carbon footprint?

- Solar power
- Wind power
- Capture methane gas at landfill sites
- Practice methane digester technology
- Manage your own organic waste
- Have waste/compost areas on-site, set aside for additional biomass
- Converting biomass into biofuel
- Partake in a programme in supplying biomass to a renewable energy manufacturing plant
- Equipment with biofuel engines
- A tree-planting project
- Produce and apply biochar
- Use electric field tractors

Q35

Which of these packaging processes do you use?

- Glass bottles
- Cans
- PET Bottle
- Bag-in-Box
- Tetrapak
- Stand Up Pouch (SUP)
- Bev Carton Elopak

Q36

What is the average weight of the glass bottle which you use?

- 300-350 g

- 350-400 g
- 400-450 g
- 450-500 g
- >500 g

Q37

Do you use drones for spraying purposes?

- Yes
- No

Q38

Biodiversity – do you set aside a portion of your land with the objective of re-greening, i.e. establishing natural vegetation to offset carbon usage?

- Yes
- No

Q39

If so, approximately what percentage of your total land is non-developed?

- 10%
- 20%
- 30%
- 40%
- 50%
- >50%

Q40

Do you measure the CO_2 emitted from the wine production during the fermentation process?

- Yes
- No

Q41

Do you sequester CO_2 from the fermentation process?

- Yes
- No

Q42

Do you irrigate your established vineyards?

- Yes
- No

Q43

Do you have a rainwater capturing programme – rainwater harvesting?

- Yes
- No

Q44

Which recycling programme do you have?

- Water/waste water
- Paper/cardboard
- Plastic
- None

Q45

What mode of transport do you use to transport your wine domestically?

- Road
- Rail
- Sea
- Air

Q46

What mode of transport do you use for exporting your wine?

- Road
- Rail
- Sea
- Air
- We do not export

Q47

In your distribution process do you bottle any wines closer to its eventual destination, the buying market?

- Yes
- No

Q48

Do you have an active Social Responsibility Programme?

- Yes
- No

Q49

Other than the above, what initiatives do you exercise in reducing you carbon footprint?

APPENDIX B – INTERVIEW WITH CARBON NEUTRAL WINE FARMER

Interview with Michael Back, owner of Backsberg Wine Estate – Carbon Neutral certified.

Backsberg

Questions

1. Prior to the CN in 2006 certification you became BWI (Biodiversified and Wine Initiative)-accredited and achieved IPW status. Were these critical in your path forward or did the one derive from the other, as you got one, you were driven to go the next step to the top?

2. What were the principles that drove you to take the step to achieve Carbon Neutrality?

3. You are organic not biodynamic? Are there any of the biodynamic principles that you follow.

4. It has been argued that organic viticulture requires more energy than non-organic through:

    - Tillage requirements
    - Spaying of copper sulphate more regularly
    - Tractor passes
    - Banned synthetic fertilisers – 40% of GHG emissions – should therefore lead to a lower footprint.

5. Which carbon calculator are you using to measure your carbon footprint?

6. You follow:
    a) Methane Digester technology – how exactly does it work?

    b) Biomass – I know that you have a plant and that, in conjunction with the German government, you fire a Biomass boiler.
    Give a brief explanation of how it works.

    c) You have equipment with biofuel engines. Which equipment and how exactly?

    d) Biochar – you manufacture and apply – how? Tell me about the BIOCHAR concept – charcoal mixed into the soil to retain water and greater effectiveness of retained nutrients.

    e) 2005 – 10% of the land for non-development
    Fynbos – 35 ha

Objective is re-greening, re-establishing natural vegetation and clearing alien vegetation.

You do that.

Tree planting project - Tell me about the greening program in Klapmuts with Food and Trees for Africa organization

f) What are your thoughts about the use of drones?

g) You don't measure CO_2 from fermentation tanks –
What do you think of the capture programme spearheaded by Miguel Torres

h) Does Backsberg harvest rainwater?

i) Which product recycling programmes are you following?

j) The use of drones – have you thought about them?

7. Which further steps are you taking in reducing the footprint?

8. Is it an internal audit or who is checking the accuracy of the calculated footprint?

9. Do you have to plant more trees if the carbon footprint is larger than initially audited?

10. What does the ISO standard for carbon auditing entail?

11. Organic waste creates digestion/breakdown and then releases methane gas – is that the process?

12. Packaging – use of PET – How do you find the durability of the wine over a long term. Spoilage?

13. The average weight of your bottle is 400 to 450 g. Do you have any lighter weights and how low can you go – 340 g?

14. You don't do Bag-in the Box or Stand Up Pouches or cartons? Your thoughts on this?

OFFSETS

1. I notice that you don't purchase carbon credits to get to your certification. Buying offsets is quite a contentious topic! It sort of defeats the objective, doesn't it? What is your take on it?

2. What happens when your audit does not come out at zero? Do you lose your certification? Assessments – self assessments?

3. How do education grants assist in achieving a lower CO_2 footprint? In terms of Offsets.

4. Tell me about the Freedom Road project which you are involved in – assisting farm workers in owning their own homes – The Freedom Road wine label is marketed through TESCO in the UK. Has the project been successful?

5. Do you use dry Ice/compressed CO_2 in your winery to protect from CO_2?

6. As Backsberg uses tractors do you take the tractor manufacturing process into account in the audit for the footprint.

7. You do no bottling at destination? Have you considered it?

8. Is carbon zero attainable? How?

9. Do you go along with the statement that there is apathy amongst SA wine producers to protect their environment?

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