Understanding the greenhouse gas emissions of Australian wine production

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In 2016, AWRI researchers applied life cycle assessment (LCA) to Australian wine production for the first time to calculate the greenhouse gas emissions associated with the production and distribution of Australian bottled and cask wine. This article presents findings from an updated life cycle assessment carried out in 2022 and makes comparisons with the original assessment.

INTRODUCTION

A sustainable business or industry can be regarded as one that shows resilience through infinite generations. Over its history, the Australian wine industry has displayed resilience in the face of a range of challenges — climatic events, disease, water availability, labour force changes, export restrictions and social license pressures. It has done this through strong connections with the land that supports our vineyards, the people in wine-growing communities and the overall Australian environment, adopting practices that ensure wine production can continue for future generations.

This concept of sustainability, backed by strong credentials, is now also becoming important on other fronts. Consumers and major retailers are increasingly aware of sustainably sourced and produced products. Wines are now purchased with a higher degree of understanding as to how the products might affect the environment, climate and communities involved. Being able to demonstrate sustainability is also becoming more important when accessing export markets. The Australian wine industry's sustainability program, Sustainable Winegrowing Australia, provides a framework for producers to demonstrate and continuously improve the environmental, social and economic aspects of their businesses. The program collects data from Australian grapegrowers and winemakers, which can also feed into life cycle assessments — a best-practice method for assessing the overall environmental performance of a product.

A QUICK REFRESHER ON LIFE CYCLE ASSESSMENT

Life cycle assessment (LCA) is a method for assessing the environmental impact and performance of a process or product in terms of its greenhouse gas emissions or carbon footprint. LCAs are generally either 'cradle to grave' — considering all impacts from extraction and processing of raw materials, energy production, use, recycling and disposal — or 'cradle to gate' — considering all impacts until the product leaves the producer. In a wine industry context, an LCA on grapes is generally performed up to the vineyard gate, ready for a winery to use the data in its own LCA. Likewise, an LCA on a bottle of wine may be performed up to the winery gate or continued through to disposal of the packaging. 'Cradle to gate' assessments are useful for intermediate products that will be further processed by another producer, such as winegrapes. 'Cradle to grave' assessments are usually used for finished products destined for the consumer. LCAs have the ability to investigate a number of differing environmental impact categories (e.g. acidification, eutrophication, ozone depletion or smog formation); however, the most common is assessment of the global warming potential (GWP), or carbon footprint of the product.

In 2016, AWRI researchers applied Life Cycle Assessment (LCA) to Australian wine production at a sector level for the first time. This work, published in Abbott *et al.* (2016), calculated the greenhouse gas emissions associated with the production and distribution of Australian bottled and cask wine. In the past year, that work has been extended, with updated modelling undertaken to better define the greenhouse gas emissions of an average litre of Australian wine in 2022. This article presents an updated life cycle assessment and a comparison against the 2016 model, understanding the key drivers of change within industry over the past six years.

USING DATA FROM SUSTAINABLE WINEGROWING AUSTRALIA

In 2016, the data for the LCA of the Australian wine sector came from Entwine Australia, one of the predecessor programs to Sustainable Winegrowing Australia. For this year's analysis, the data came from Sustainable Winegrowing Australia. The 2016 LCA included data from members covering 25% of the Australian vineyard area, whereas the 2022 assessment includes data from 38% of Australia's total vineyard area. This reflects significant membership growth for the Sustainable Winegrowing Australia program over recent years and increases the accuracy and diversity of the data going into the LCA. The winery data used in 2022 represents a similar proportion of the volume of Australian wine production as it did in 2016 (43% versus 44%, respectively, of total Australian production); however, since 2016, Sustainable Winegrowing membership has been adopted by more small and medium wine producers than were included in 2016, again strengthening the diversity of the data.

DEVELOPING AN UPDATED LIFE CYCLE OF AUSTRALIAN WINE

Life cycle analysis models were developed using primary production data from the Sustainable Winegrowing Australia database. Wineries and vineyards in the database were divided into three separate size categories (Table 1). These were then scaled up to represent the overall breakdown of vineyard and winery sizes in the Australian wine sector, according to data from peak industry bodies. Further data was extracted from recognised sources including the Australian Bureau of Statistics and the Bureau of Meteorology, as well as through engagement with suppliers in domestic and global markets. Data for input materials and processes not captured in the Sustainable Winegrowing Australia database were extracted from globally recognised life cycle assessment databases (e.g. AusLCI Unit and Systems processes, Ecoinvent 3.8, Agrifootprint version 6), assisting with the detailed modelling of transportation, packaging and distribution. Standard 500-gram glass bottle weights were assumed.

The base model included the proportion of wine sold domestically and exported, as well as the different formats in which they are delivered, sourced from Wine Australia export data from 2022 (Table 2). Export sales for Australian wine decreased by 3% compared to the 2016 model. The proportion of wine exported in bulk increased by 5%.

Four types of distribution of Australian wine were modelled, aiming to represent, by volume, the greatest proportion of our industry's production:

- Australian wine packaged in cask and distributed in the domestic market (domestic cask).
- Australian wine packaged in glass bottles and distributed in the domestic market (domestic bottle)
- Australian wine exported in bulk and packaged in the destination market prior to distribution within that market (export bulk).
- Australian wine exported in bottle and distributed within the destination market (export bottle).

Table 1.Vineyard and winery size categories used in the LCA model

Size category	Vineyards (ha)	Wineries (t)
Small	< 25	< 2000
Medium	25 - 50	2,000 – 10,000
Large	> 50	> 10,000

Table 2. Sales formats for Australian wine

Domestic sales	39%	Export sales	61%
Cask/ bag-in-box	32%	Bulk	62%
Bottle	68%	Bottle	38%

Table 3. Global recycling rate for glass bottles 2016 vs 2022

Market	2016	2022
Europe	47%	52%
Australia		
(Asia Pacific)	25%	40%
North America	25%	33%

OVERALL, A DECREASING CARBON FOOTPRINT FOR AUSTRALIAN WINE

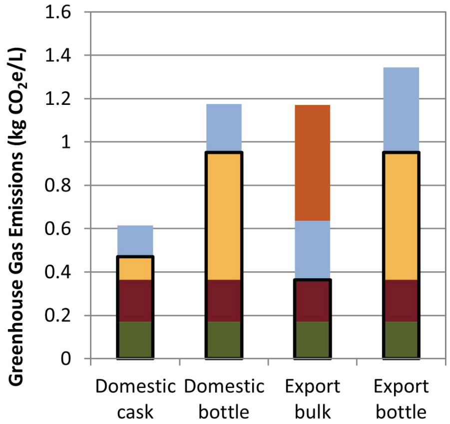
Using the updated data sources, the average 'cradle to grave' carbon footprint of Australian wine in 2022 was calculated to be 1.05kg CO_2e/L. This result is 10% lower than that found in the 2016 study (1.16kg CO_2e/L). As with results of both studies, outcomes should be taken with some caution as the data and the analysis have not been independently verified, which is a requirement when making comparative assertions.

The question is sometimes asked as to why a life cycle analysis of wine production does not include the biogenic CO_2 emissions from fermentation. Consistent with the approach taken for all agricultural systems, biogenic carbon flows are not included within the accounting as these flows exist as part of the short-term carbon cycle. This includes processes such as photosynthesis by plants, which removes CO_2 from the atmosphere; and the subsequent breakdown of organic matter, which re-releases it to the atmosphere, generally existing in a net zero balance. Wine production is heavily based on the biogenic carbon cycle. Grapevines sequester CO_2 from the atmosphere and convert it into sugar and biomass which are harvested and transported to the winery. Some of the carbon is converted back to CO_2 during the fermentation process, some remains in the resulting wine, some is converted to CO_2 during wastewater treatment, and the remainder is contained in grape marc which is often returned to the vineyard as fertiliser, where it ultimately breaks down, returning to the atmosphere. While fermentation emissions are not included in the scope of the LCA, capture of these emissions could be a viable opportunity for offsetting other intractable CO_2 emissions, further lowering the total footprint of production.

The emissions of Australian wine based on their distribution pathway are shown in Figure 1, comparing results between the current study and the 2016 results (Abbott *et al*. 2016).

The 'cradle to gate' impacts shown in Figure 1 demonstrate the importance of performing LCA over the whole process, not just to the winery gate, as there are major contributions of emissions from steps occurring outside that boundary. Some interesting similarities and differences were evident between the 2016 and 2022 studies. Transport and glass packaging were again

2016 LIFE CYCLE ASSESSMENT



2022 LIFE CYCLE ASSESSMENT

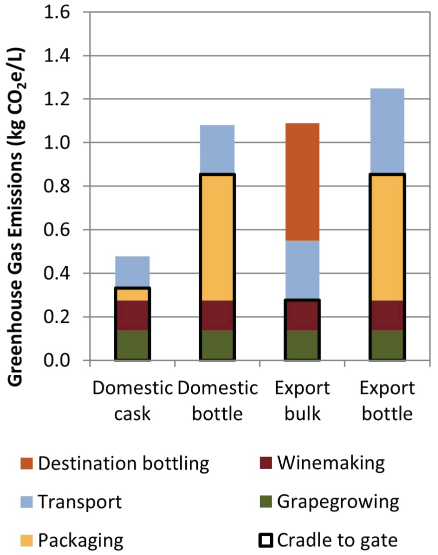


Figure 1. Greenhouse gas emissions over the life cycle of Australian wine delivered to domestic and export markets in different packaging formats, showing both 'cradle to grave' and 'cradle to gate' emissions. Graphs compare the current study against the 2016 life cycle assessment (Abbott *et al*. 2016).

highlighted as emissions hotspots, together representing approximately 74% of the total life cycle (a contribution increase of 6% compared to 2016). Grapegrowing and winemaking each gave similar contributions at 13%, showing a reduction in their share of the overall footprint. Within both grapegrowing and winemaking, emissions attributed to electricity use, including electricity used by irrigation providers, were a key driver in the observed reduction from 2016. Over the past six years, there has been a significant increase in the proportion of renewable energy sources as a proportion of generation across all states. South Australia, the largest production state for grapes and wine, has increased its renewable energy contribution by 18%. Victoria, New South Wales and

Western Australia have also increased their renewables penetration by 17%, 14% and 18%, respectively (Clean Energy Council 2016, 2022) (Figure 2).

Detailed breakdowns of emissions contributions for grapegrowing and winemaking are shown in Figure 3 and Figure 4, respectively. For grapegrowing, diesel use is the largest contributor to emissions, while electricity (predominantly for refrigeration) continues to drive emissions in the winery.

Overall, and as highlighted in Abbott *et al.* (2016), wine exported in bulk is less emissions-intensive due to lower emissions in shipping, as the glass weight is not transported. The footprint from exporting wine in bulk and packaging in international markets is similar to that of packaging wine in glass bottles and distributing it in Australia. This is driven by a combination of the improved recycling rates in the primary export markets (Table 3) and the higher renewable energy contribution within these markets compared to within Australia.

PACKAGING FORMAT

With the increase in recycling rates of glass, there are noticeable decreases in the emissions associated with the use of glass bottles. However, a sensitivity analysis assessing the indicative carbon footprint of alternative packaging formats, including bag-in-box and lightweight glass bottles, suggested that emissions reductions can be achieved more quickly through a change in packaging (Figure 5) than through increases in glass recycling. A 2L bag-in-box format, for example, can reduce the life cycle emissions from packaging by 45% relative to a standard 500g glass bottle. Recent industry trends show that packaging is front of mind for sustainable producers, driven primarily by the awareness of the emissions associated with glass. Some caution is needed when considering alternative packaging options, however, as it is important that the technical performance of the product (e.g. shelf life) is not compromised.

SUMMARY

This study of emissions associated with the production and distribution of Australian wines found a 10% reduction in emissions compared to a similar study conducted in 2016.The most significant change between the two studies was the increasing proportion of renewable energy in Australia. Increases in the proportions of bulk wine export and the glass recycling rate within export and domestic markets also drove emissions reductions.

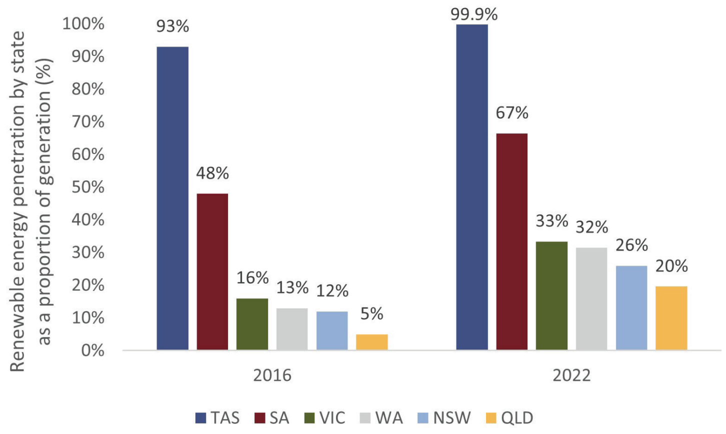


Figure 2. Renewable energy penetration by state as a proportion of generation in 2016 versus 2022 (Clean Energy Council 2016, 2022).

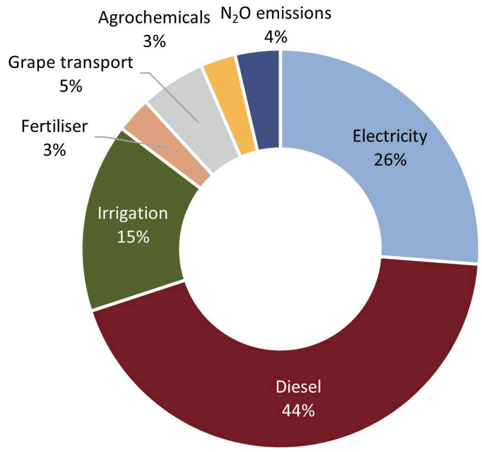


Figure 3. Sources of greenhouse gas emissions in Australian viticulture.

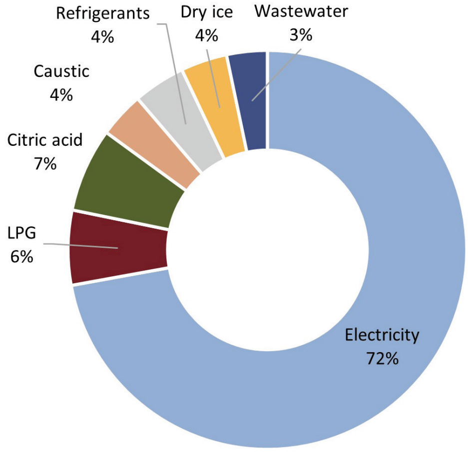


Figure 4. Sources of greenhouse gas emissions in Australian wineries.

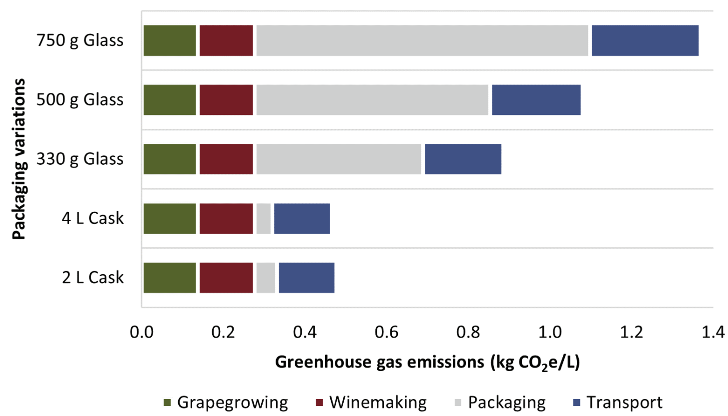


Figure 5. Differences in greenhouse gas emissions associated with packaging type as modelled for domestic distribution.

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