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Abstract

Between 1995 and 2014, California wine production increased by 79%. While the industry has made significant efforts to improve environmental performance, existing data on water consumption and CO_2 emissions often rely on studies from foreign regions, which may not accurately reflect California's specific production schemes. Because environmental profiles vary widely based on life-cycle factors, this study utilizes Life Cycle Analysis (LCA) to assess the impact of red wine produced on the Central Coast of California under various production scenarios.The cradle-to-gate analysis examined variables including bottle weight reduction, transportation distances, and varying ratios of machine versus hand-harvesting. Results revealed that the bottling process contributes the most significant environmental impacts, accounting for 82.6% of total global warming potential (GWP) and 65.4% of eutrophication potential. Furthermore, transportation and bottle weight are critical factors, contributing 10.6% of ecotoxicity potential, 11.6% of GWP, and 7.84% of eutrophication potential. Notably, reducing bottle weight by 26.1% resulted in a 20.0% reduction in GWP and a 13.2% reduction in eutrophication potential.These findings provide a scientific basis for producers to adopt best practices for environmentally conscious wine production and inform consumer decision-making. Additionally, these results facilitate the assessment of produce against established sustainability standards. Given the regional variability of certification programs across California and the United States, this data offers a quantitative basis for streamlining audit procedures and supporting the overall certification process.

Key Words: Life-Cycle Impact Assessment (LCA), California, Central Coast, Red Wine Production, Environmental Impact, Price

Introduction

Accelerating climate change presents complex scientific, socioeconomic, and environmental challenges, necessitating that resource-dependent industries quantify their ecological footprints and implement sustainable production frameworks. The viticulture and enology sectors occupy a critical position within this transition, representing a synthesis of legacy agricultural practices and the evolving requirements for sustainable economic development in the United States. California, the state of interest in this study, sees local governments spearheading progress on general planning activities in accordance with sustainability goals. Additionally, as a diverse state encompassing a large land area, California sees major variances in income, size, and political orientation across cities (Bedsworth and Hanak 2013). These differences in public opinion and perspective force local governments and industries into a position of accountability to actualize sustainability goals on a large scale, especially in those industries which contribute highly to greenhouse gas emissions, such as agriculture.

At the same time, recent market research indicates a significant demographic shift, with younger cohorts, particularly Millennials and middle-aged consumers, demonstrating a heightened prioritization of environmental stewardship compared to previous generations. These consumers increasingly view sustainability as a core purchase driver, often correlating frequent wine consumption with a willingness to pay a premium for verified sustainable production. This trend underscores a growing segment of well-educated, urban-dwelling consumers who actively seek alignment between their purchasing decisions and ecological values (Kelley et al. 2022). This increased consumer awareness has driven demand for sustainable and environmentally friendly products (da Silva and da Silva 2022). Wine production is an international multibillion-dollar market, and wine trade is steadily increasing. Additionally, wine production is deeply intertwined with the agricultural sector, which accounts for roughly one-fifth of global greenhouse gas emissions (da Silva and da Silva 2022). While agricultural sustainability is a highly explored topic, the wine sector has not seen the same trend (Alessandri, Daddi, and Iraldo 2024). In 2020, the global export market of wine was valued at 29.6 billion Euros, with 7.3 million hectares dedicated to wine production. In the United States, the world's largest wine producer, consumer, and importer, local governments have significant potential to catalyze major policy changes that further national commitments to sustainability (Lapsley, Alston, and Sambucci 2019).

In 2017, grapes were considered the most valuable crops in California, with 829 thousand acres dedicated to growing grapes for the wine industry—an industry that produced 6.5 million tons of grapes worth $5.7 billion, $3.6 billion of which was attributed to wine grapes (Alston, Lapsley, and Sambucci 2020). However, the California wine industry is becoming increasingly vulnerable to the effects of climate change, especially in wildfires, which have increased in frequency and severity in recent years. In 2020, the wildfires caused billions of dollars in damage to wine production schemes, and despite overwhelming support for creating more sustainable infrastructure, many growers do not believe they have enough information to make their operation more sustainable (Zakowski et al. 2023). Thus, to protect the future of California's wine industry, a more concerted effort is needed to address the environmental impacts of production.

As the industry continues to grow, the environmental impact of wine grows as well. Although there have been studies quantifying the environmental impact of a bottle of red wine, most have been conducted in Europe (Table 1). The major tool for examining these impacts is Life Cycle Analysis (LCA). LCA results of environmental impacts can vary significantly depending on the geographical location of wineries and vineyards. This is due to large regional variations in environmental characteristics that influence the ways in which grapes grow prior to wine production such as soil, topography, and climate. Production of a single bottle of wine requires 0.4 to 0.8 liters of water consumption, depending on the region in which it is produced (Pattara, Raggi, and Cichelli 2012; Neto, Dias, and Machado 2013; Gazulla, Raugei, and Fullana-i-Palmer 2010; Christ and Burritt 2013; Comandaru et al. 2012). Furthermore, carbon dioxide emissions fall between 0.41 and 1.6 kg due to the variations in grape cultivation, vineyard management, and wine making scheme (Meneses, Torres, and Castells 2016; Vázquez-Rowe, Rugani, and Benetto 2013; Iannone et al. 2016).

These global trends are also true in the context of California's wine industry. With a stable increase of 15.6 million gallons of wine produced per year, wine production in California has increased by 79% between 1995 and 2014. California is vital to wine production in the United States, producing over 86% of all the country's wine alone (Wines&VinesAnalytics

2018). Furthermore, California's Central Coast produces 8% of the red wine in California and has a significant presence in both domestic and foreign markets (USDA 2018). The variation of environmental impacts of the wine industry between regions on a small scale remains true as well. Between two cities in California, Napa and Lodi, different grape yields and harvesting practices, such as the machinery configuration, have caused Napa wineries to contribute twice the amount of Global Warming Potential on a per mass basis of grapes (Steenwerth et al. 2015). California alone yields several different microclimates across the state that vastly contribute to the unique terroir of each region. Because of this, focusing on the Central Coast terroir will produce different data than that of other Californian regions (Puckette 2017).

The California wine industry is constantly examining methods to reduce environmental impacts. Because of growing consumer interest in sustainably made wine, more wine companies are reflecting on the environmental impacts of their practices. This growing awareness has ultimately led to a shifted approach towards sustainability. Working to be at the forefront of sustainability efforts, the California Wine Growers Association created the Sustainability in Practice (SIP) program. SIP is a third-party certification that wineries can obtain through sustainable practices, such as reduction in water and pesticide use (SIPCertified.org 2018). The California Sustainable Wine Growing Alliance also created the Certified California Sustainable Winegrowing Certification to strengthen communities and the environment through improvement of the quality of air, water, and habitat (CCSW 2010). Now, 70% of wine produced in California is produced in sustainable wineries certified by the California Sustainable Wine Growing Alliance (CSWA 2018). In California, there is already substantial movement towards more sustainable practices that will reduce environmental impacts and improve the system overall. The results of this study will ideally contribute to further environmental research in California, such as the BEST Winery Guidebook that benchmarks energy and water savings for the wine industry (Galitsky et al. 2005). The LODI RULES for Sustainable Winegrowing is another noticeable program serving as a foundational third-party certification framework, encompassing over 150 science-based standards across six core pillars: business, human resources, ecosystem, soil, water, and pest management. A distinguishing technical feature is its Pesticide Environmental Assessment System (PEAS), a quantitative risk-tracking model that ensures chemical applications remain below established ecological thresholds. Now certifying over 75,000 acres globally, the program's rigorous, peer-reviewed structure has provided the functional blueprint for subsequent sustainability frameworks, including the California Sustainable Winegrowing Alliance (CSWA), by effectively integrating economic viability with high-precision environmental monitoring (Lodi Winegrape Commission 2025).

In California, wine price is substantially more affected by the type of grapes that comprise the wine as opposed to the region in which it was grown (Zhao 2008). The environmental inputs that are necessary to represent grape type included in this model are grape yield, water use, and fertilizer application; these factors greatly influence pricing. By comparing cheap and expensive wines and analyzing their different environmental impacts, recommendations can be made to the industry that will benefit both producers and consumers. As the California wine industry strives to create more sustainable wine, the expansion of the environmental portfolio becomes imperative. Overall, a strategy to reduce emissions will not only benefit wineries of the California Central Coast, but also the global wine market. This study focuses on quantifying the environmental impact of red wine produced in this region to better understand the environmental profile of Californian wine and identify key changes that can be made to improve sustainability.

Table 1: Summary of Different Wine Producing Region’s Grape Yields and Environmental Impacts. In the Italian wine scenario, RHQ and RMQ refer to red high quality and red medium quality wine, respectively.

Table 1: Summary of Different Wine Producing Region's Grape Yields and Environmental Impacts								
Geographical Region	Grape Yield (kg)	Fertilizer (kg)	Pesticide Sulfur (kg)	Water Use (L)	Energy Usage (MJ)	Global Warming Potential (kg CO2 Eq)	Eutrophication Potential (kg PO43−eq)	Reference
Spain (Catalonia)	-	2.83E-02	4.08E-04	1.36E+00	-	9.51E-01	1.78E-04	(Meneses et al. 2016)
Spain (Tuscany)	1.07E+00	4.37E-03	9.38E-03	1.72E+00	-	3.41E-01	-	(Vázquez-Rowe, Rugani and Benetto 2013)
Italy Wine 1 RHQ	1.47E+00	-	-	-	1.89E+01	1.58E+00	2.63E-04	(Iannone et al. 2016)
Italy Wine 2 RMQ	6.59E-02	-	-	-	1.07E+01	7.49E-01	9.61E-05	(Iannone et al. 2016)
Note: All studies used a functional unit of a 0.75L bottle of red wine.								

Methodology

Goal and Scope

The aim of this study is to determine the environmental performance of a bottle of red wine produced on the Central Coast of California. This study seeks to evaluate the distinctions between high- and low-quality wines and how environmental performance might affect the criteria for quality within the wine industry. For the purposes of this study, the wine-making process is divided into three main components: the viticulture stage, the vinification stage, and the bottling process. These three main components make up each of the three unit processes used in the study and will be further explained in the following sections. The system boundary of this study is cradle-to-gate, including all upstream and core stream processes except capital development components such as vineyard creation, winery construction, or waste management stages of the wine life cycle (Figure 1). Red wine serves as a better subject than white wine for this study specifically because of its broader use in the industry and its higher diversity of inputs and processes. Thus, the assigned functional unit was one 0.75L bottle of red wine, as 73% of papers in a comparative study utilized this value as a standard unit (Zambelli et al. 2023). All analyses were conducted in the sustainability modeling software Open LCA Vers. 1.7.4. Data was obtained from interviews of local wineries on the Central Coast, previous related LCA studies conducted on the wine industry, and a commercial dataset, Ecoinvent vers. 3.2. Data collection was prioritized from most valued to least valued in the following order: Local Winery Interviews, Central Coast data, California data, and European data that utilized the same functional unit.

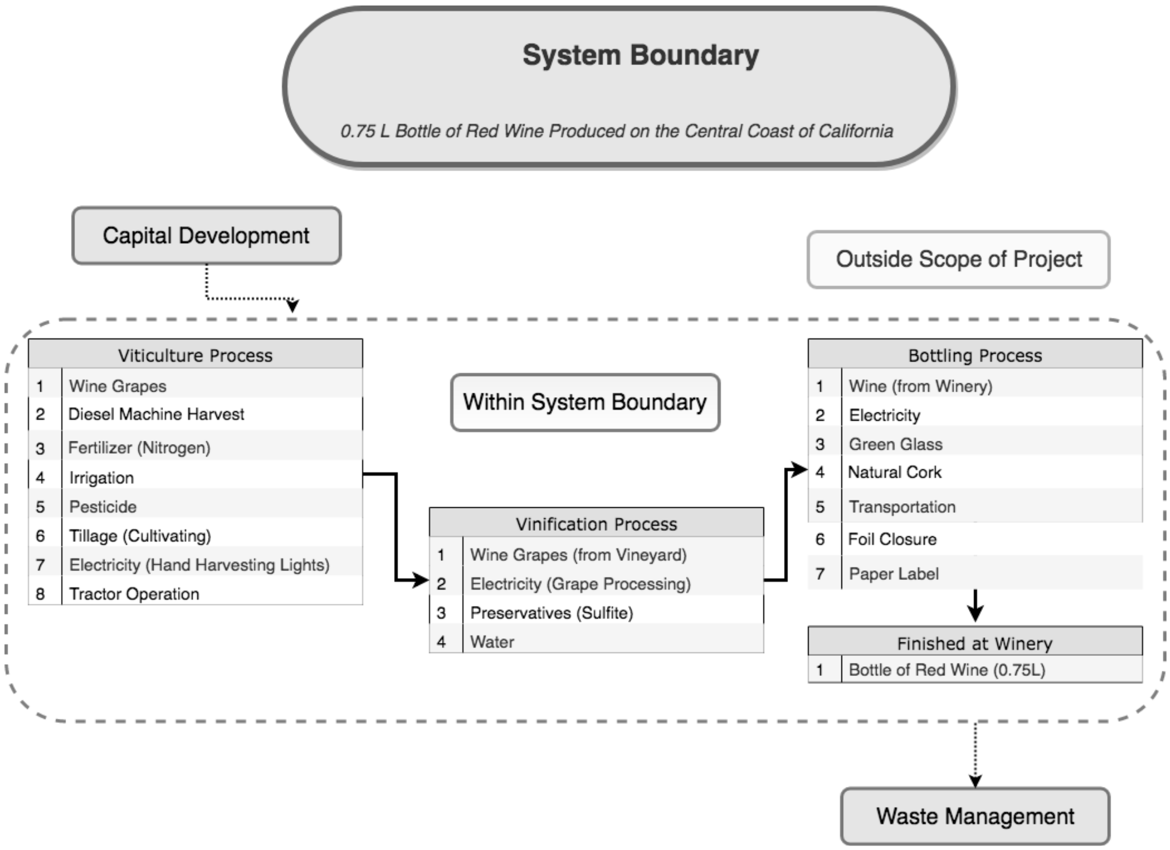

Figure 1: A system boundary for the inputs needed to create one 0.75L bottle of red wine produced on the Central Coast of California (Created in Draw.io)

Grape cultivation and harvest

The first unit process in the study involved the analysis of the process of the growing and harvesting of grapes for winemaking. The study began by analyzing the agrochemicals involved in viticulture. The total wine grape production area for the Central Coast of California was determined to be approximately 119,000 acres (Alston, Lapsley, and Sambucci 2018). Average fertilizer and pesticide amounts were approximated at 26.07 kg per acre, and 1.22 kg per acre, respectively (Carlisle et al. 2010; Ough, Stevens, and Almy 1989; Christensen et al. 1994). The values that represented fertilizer in the model were derived through averaging data from recommended literature on both organic and conventional fertilizer varieties. These values were obtained from different American Viticultural Areas (AVA) to best represent the varying usage of fertilizers and pesticides in California.

Water requirements are another important consideration within wine production. Associated literature from the Napa and Lodi wine producing regions provided an averaged value of 98.9 Billion L, which was adjusted to fit the acreage of the Central Coast (Steenwerth et al. 2015). This value was determined by considering the changing water demand of plants during their growth season, while also accounting for evapotranspiration.

This unit process also includes the use of tractors for the application of pesticides and fertilizers, tilling, and harvesting, which comprise the energy inputs for this process. In the Central Coast, grapes are intensely harvested when they have matured typically between the months of September and October(Wineinstitute 2018). A key distinction between high- and low-end quality wines is the use of hand-harvesting methods during the viticulture process. The use of hand-harvesting methods requires additional resources such as power tools, tractors for transportation of the grapes, and flood lights(Steenwerth et al. 2015). These additional inputs were incorporated into the model during the scenario analysis. High-end wines were given parameters that define 70% of the grapes are harvested by machine and 30% by hand, whereas low-end wine had parameters set that define 100% of the grapes are harvested by machines. This 70% machine harvesting rate for our BAU was utilized based off the information gathered from local winery interviews(T&NWinery 2018). Grape harvest was modeled at night because night harvest typically yields higher wine quality and safer conditions for worker because of reduced temperatures. The use of harvesting machinery, as well as additional tractor use for transportation is represented by 9.09 million kg of diesel(Carlisle et al. 2010). Hand-harvesting techniques are known to be able to increase precision in grape quality control, however, this harvesting technique does introduce more costs and is more inefficient (Clary et al. 1990).

It was assumed that the vineyard represented in this model is on the same property as the winery, resulting in minimal transportation costs for the grapes being brought to the winery for the vinification process. Additionally, although it is common practice to use a blend of various wine grapes, it is assumed that one type of grape is used throughout the unit processes for the purposes of this study.

Vinification

The vinification process involves destemming and crushing the grapes into must, fermenting of the must, and then cooling of the wine, and is often considered one of highest-emitting steps in the wine-making process, thus being a point of attention when making systems more sustainable (da Silva and da Silva 2022). This unit process included the output flow from the viticulture stage and other pertinent input flows associated with vinification. Sulfite (SO_3^{2-}), a preservative used in wine making was determined to be used at a value of 0.1mg/0.75ml of wine (Gazulla, Raugei, and Fullana-i-Palmer 2010). This preservative functions to prevents oxidation and promotes antibacterial conditions within the wine after it has been bottled. The water use for vinification was 4.5L/bottle and functioned in sanitation of the steel storage tanks(Styles, Layous, and Crable 2014). Secondary fermentation where the wine develops the majority of its flavor was modeled to have an aging duration of 1 year in a stainless-steel tank(Puckette 2018). Aging of wine in oak barrels was not considered in this study because of a lack of original data, as well as, a reliance on inconsistent literature. The literature surrounding the duration of barrel use, the number of barrels used, their proportion compared to steel tank usage, and their associated upstream and downstream processes were inconsistent, and therefore, unreliable. The refined and aged product was then ready for bottling.

Bottling

The most significant input in this process was the glass bottle. The BAU bottle weight was 656.85g, this number was obtained by calculating the median mass range of several glass bottles(SaxcoInternational 2019). The glass flow chosen in the LCA analysis was green packaging glass. This type of glass was utilized because green glass functions to protect the wine inside from UV rays(Puckette 2018).The transportation types needed for this process were a transoceanic ship and a lorry for international and domestic bottle transport, respectively. The BAU scenario consisted of sourcing the bottles from China, with a 12,000 km nautical trip. This number was not a straight-line distance, but instead was calculated from a shipping company's reported estimate, stopping at the appropriate ports and utilizing the optimal shipping routes. The Port of Long Beach was selected as the shipping destination because it is the closest port to the Central Coast capable of accommodating for the large volume of shipments. The goods were transported an additional estimated 336 km by land transportation to the Central Coast.

In terms of energy inputs, 18% of the total electricity needed throughout the process occurs in bottling and storage. This use of this electricity includes climate control to maintain wine quality and energy used in sanitation of bottles (de Castro et al. 2024). Cork weight was obtained from measuring multiple natural cork closures and taking an average of the weight. Natural cork was the closure selected for the BAU because the impacts of natural cork and agglomerated corks were similar because agglomerated corks are a byproduct of the natural cork making process (Goode 2011). The paper label's weight was also averaged from similar studies. An aluminum foil capsule was selected because the wineries that were modeled used foil primarily over the plastic or no closure options. Distribution of the wine bottles to the market was not included in the model.

Scenarios and Parameters

The methodology first consisted of creating a Business-As-Usual (BAU) scenario that represents the standard inputs required to create the functional unit. Values obtained for the model represent the way in which the model will operate under standard conditions. The BAU serves as a basis for the comparison of price-affecting parameters. Price-affecting parameters are the components of the model that allow for the comparison of the input flows that most dramatically affect the price-to-impact relationship examined in this study. The three parameters used were differences in the following categories: harvesting techniques (machine or hand), transportation distances (source of bottle manufacturing), and bottle weights used (heavier or lighter). The two main scenarios were a high-price, heavier, imported bottle that utilized 50% hand harvesting and 50% machine harvesting (HPCN), and a low-price, domestically produced bottle that utilized 100% machine harvesting (LPUS). These parameters were the variables adjusted in order to test the impact of the four other scenarios to the BAU (Table 3). The BAU, High-Price China (HPCN), High-Price United States (HPUS), Low-Price China (LPCN), and Low-Price United States (LPUS) were the five scenarios being tested. In the USA bottle sourced parameter, the inputs were 416 km for a truck on the road, whereas if the bottle was sourced from China the inputs were 12,000 km on a transoceanic ship in addition to a 336 km trucking distance after the bottles were released from the port. In terms of the HP and LP scenarios, the high price point was partially due to the cost of a heavier bottle. Wine cost is not only a function of the quality of the wine, but also the weight of the bottle due to material and transportation costs (SaxcoInternational 2019).

Table 3: Parameter affected by price. Table that demonstrates how the different parameters (Harvesting, Bottle Weight, and Bottle Source) were manipulated in each of the five different scenarios: Business-as-usual (BAU), High-Price-China (HPCN), High-Price-US (HPUS), Low-Price-China (LPCN), Low-Price-US (LPUS).

<table>
<tr><th colspan="12">Price Affecting Parameter Table</th></tr>
<tr><th colspan="2">Parameters</th><th colspan="2">BAU</th><th colspan="2">HPCN</th><th colspan="2">HPUS</th><th colspan="2">LPCN</th><th colspan="2">LPUS</th></tr>
<tr><td>Machine Harvest (%)</td><td>Hand Harvest (%)</td><td>70</td><td>30</td><td>50</td><td>50</td><td>50</td><td>50</td><td>100</td><td>0</td><td>100</td><td>0</td></tr>
<tr><td colspan="2">Bottle Weight (g)</td><td colspan="2">656</td><td colspan="2">771</td><td colspan="2">771</td><td colspan="2">570</td><td colspan="2">570</td></tr>
<tr><td colspan="2">Bottle Source (Country)</td><td colspan="2">China</td><td colspan="2">China</td><td colspan="2">US</td><td colspan="2">China</td><td colspan="2">US</td></tr>
</table>

Harvesting Techniques

Within the wine industry, two dominant methods of grape harvesting exist. Machine harvesting involves the use of heavy agriculture machinery to perform the harvesting mechanics such as cutting, collecting, and pruning. The fuel requirements for this technique comprise of majority of its environmental impact. Hand-harvesting makes use of labor to perform the mechanics of the harvesting process. However, this method requires additional supporting infrastructure and tools such as floodlights, tractors for hauling, and hand tools. The low-price wine scenario sets a proportion of 100% machine use in its harvesting methods; while the high-price wine scenario makes use of a 50/50 split between hand and machine harvesting techniques (T&NWinery 2018). Higher end wineries generally use more hand harvesting in their practices because of its presumed higher quality grape yield. The BAU scenario is set to a 70% use of machine and 30% hand harvesting method.

Bottling Sources: Distance & Weight

Transportation distances were analyzed by comparing bottles produced in the United States (US) and those produced in China (CN). The US and CN were selected as the countries of origin for glass bottles because they are both major produces for the wine market (Goode 2011). The largest wineries in California have the capacity to produce their own wine bottles domestically and have access to wine bottles at an affordable cost (GalloGlass 2019). On the other hand, small to medium scale wineries rely on importers to affordably source their bottles.

For smaller wineries, ordering bottles domestically is less realistic because the minimum order quantity may not be at an affordable price point and may not allow for a flexibility in bottle design specifications (Winebusiness 2019).

Bottle weight, as a parameter in the model, does the most to distinguish low priced wine from high priced wine. Bottle weights were determined by compiling data from the low-price bottle distributor websites (SaxcoInternational 2019). A list of each wine bottle's weight and price was taken, and averages for each were determined in order to develop a quantitative description for high and low-priced bottles. The glass weight was set to 771.1 g high-price (HP) parameter, 569.9 g for the low-price (LP) parameter, and 656.9 g for the BAU parameter. These values reflect the general trend of an increase in wine price as bottle weight increases. This trend is apparent because an increase of bottle weight requires more material, energy, and associated transportation costs.

Results

Process Comparison

A scenario involving the comparison of all three unit processes was performed. Using TRACI 2.1 software to run the LCIA, impact results showed significant ratings for the carcinogens, ecotoxicity, and non-carcinogens categories after normalization, with values of $1.55e^{-4}$, $4.72e^{-5}$, and $4.16e^{-5}$; respectively. The bottling process is shown to be considerably more impactful than the other two processes, accounting for roughly 70% of the impacts to ecotoxicity (Figure 2). This is not surprising given that each process incorporates the burden of the previous one. Also, the glass bottles themselves contribute a large portion of the impacts. They comprise of about 43.3% of the total environmental burden of the bottling process, with regards to carcinogens. After performing LCIA analysis, the flow identified with having the highest impact to human health (carcinogens) was "treatment of spoil from lignite mining."

LCIA suggests that the portion of impacts resulting from the viticulture stage in the life cycle of red wine are miniscule when compared to the other processes. The model shows the vinification stage of the life cycle as marginally more impactful. The bottling phase of the life cycle is responsible for the largest proportion of the total environmental performance of the functional unit. This is especially true, in the acidification category where about a 90% increase occurs between the vinification and bottling processes (Figure 3).

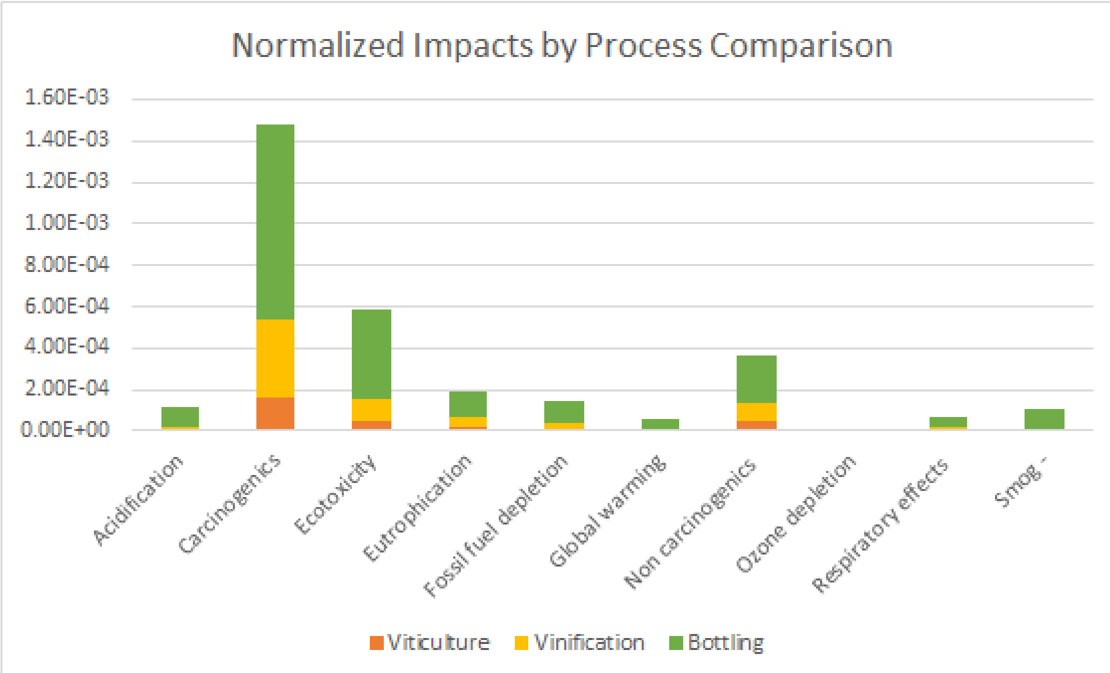

Figure 3: This chart shows the impact categories for the process comparison scenario.

After normalization using Traci 2.1 software, the model suggests that the most considerable impact categories related to the environmental performance of a bottle of red wine are human health potential (carcinogens and non-carcinogens), ecotoxicity, and eutrophication.

High-Price and Low-Price Comparison

Scenarios comparing the price affecting parameters were performed using TRACI 2.1 LCIA software and the parameters were adjusted to represent the high, low and BAU average wine prices. The results produced by the model show that the parameters with the highest contribution to the environmental performance are glass weight and travel distance. High-priced wine sourced from China performs the highest in all impact categories, while low-priced wine sourced domestically contributes the least in all categories.

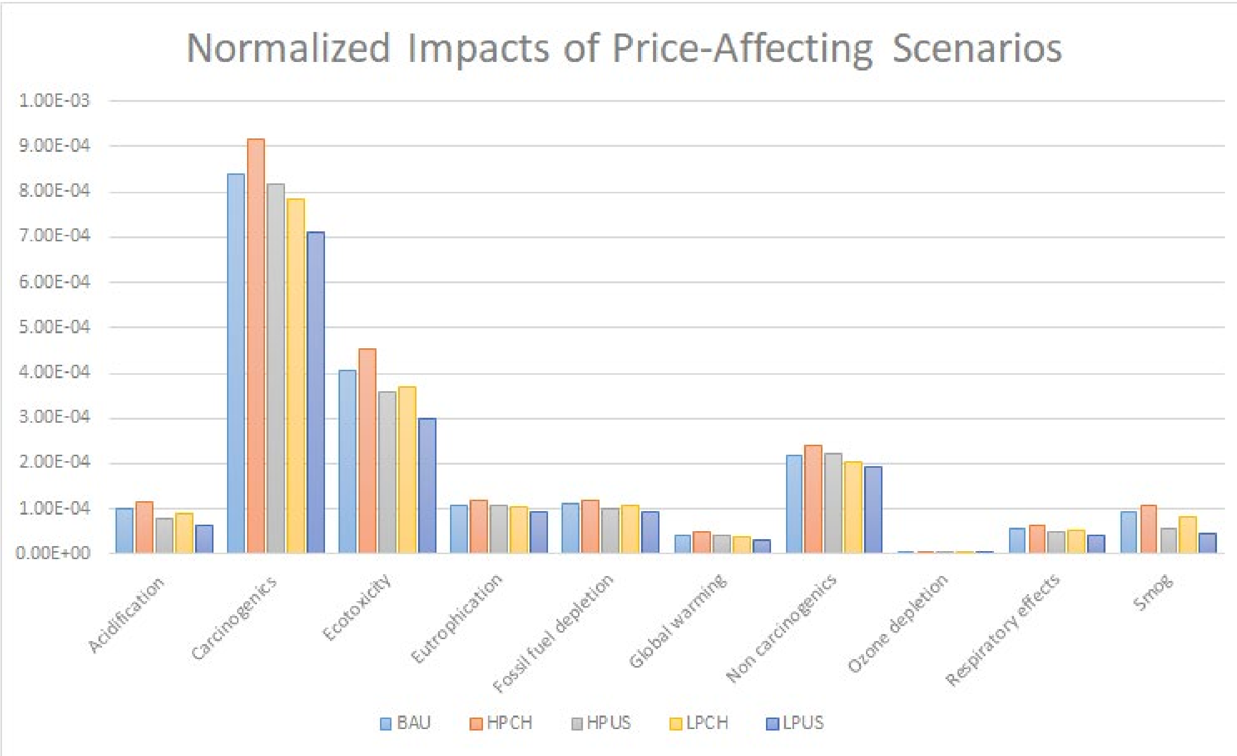

Figure 4: Chart showing the normalized impacts of the five different pricing scenarios.

The BAU scenario serves as a reference scenario for comparison between the different pricing parameters. It was generated by using the exact input values used to build the model. Price affecting parameters did not influence this scenario. In most categories, the BAU scenario ranks as the second most impactful scenario. The HPCN scenario involved the increase of glass weight by 14.8% from the BAU setting.

Discussion

Comparisons to Other Studies

Similar literature related to the environmental performance of wine shows some congruency with this study. Particularly, with regards to the impacts of glass bottle use. A study analyzing the impacts of wine from Catalonia, Spain found similar results on bottle contribution to environmental performance (Meneses, Torres, and Castells 2016). Their study found the bottling subsystem to contribute approximately 79.6% of the total Human Toxicity impact category. Bottling also scored highest in most of the other categories used for analysis for this study. Furthermore, the results for Global Warming Potential (GWP) from related literature reflect similar trends found in this study; with 1.58 kg CO_2 eq comparing to this study's result of 1.02 kg CO_2 eq from the bottling process (Iannone et al. 2016) Of course, differing methodology practices will introduce some inconsistencies when comparing two studies; however, a quick comparison helps to show the related-ness of this research to the existing body of wine LCA literature.

Normalization Techniques

A key aspect in LCA studies is the method of normalization. Normalization aligns the model with existing data on the environmental impacts of specific flows. In the case of this study, since TRACI 2.1 LCIA software was used to conduct the scenario analysis, normalization was set using TRACI 2.1 US 2008 reference data. This aligned the model with the data for the United States in 2008 so that it can have reference point to compare impacts. This comparison is necessary to ground the results in a realistic value set and allow for easier data interpretation

Leading Impact Categories

One clear observation made in this study is that the most impacted category in the wine making process is Human Health Potential (HHP), consisting of both the carcinogens and non-carcinogens categories. Figure 4., demonstrates the large disparity in impact between the carcinogens category and any other category. LCIA analysis showed that the single most impactful flow in the carcinogens category of the bottling process is the treatment of spoil from lignite mining. This suggests that in order to make meaningful remediation in the environmental performance of red wine, concern should be focused on reducing impacts to HHP.

Another category of significant ranking in the scenarios analysis is the ecotoxicity category. The bottling process is responsible for most of this impact, and the HPCN scenario ranks most impactful in this category, suggesting the amount of glass used to produce a bottle of wine has the most direct effect on its performance in ecotoxicity. Similarly, the flow with the largest impact to this category is also treatment of spoil from lignite mining. The use of glass bottles in the wine industry contributes the most to the release of toxic chemicals beyond maximum tolerable concentrations into ecosystems.

Bottle Weight & Transportation

The most contributive parameters affecting the outcome of this study were the amount of glass used for bottling, and the distance of glass distributors from the winery. Unequivocally, the bottle weight parameter accounts for the most influence on environmental performance. This can be exemplified by the difference between the HPCN scenario and the LPCN scenario, which shows that a reduction in bottle weight by just 26% (201.2g) can lead to a significant reduction in most impact categories; such as, Carcinogens by 14.5%. In addition, the transportation parameter also accounts for significant changes in environmental burden, with a 21% difference in Ecotoxicity impact between the HPCN scenario to the HPUS scenario. If bottles are sourced domestically, impacts to most of the categories can be expected to reduce. Manipulation of these essential parameters generates the most difference in the model's results; therefore, recommendations for optimization of the environmental performance of wine should be based on these price-affecting parameters.

Conclusions

This study was conducted in order to identify the environmental impact of a bottle of red wine produced on the Central Coast. This study also sought to understand how price affects environmental impact and identify knowledge gaps in the data. By reducing bottle weight, and other price affecting parameters, there can be a significant reduction in environmental impacts associated with wine production. Knowledge gaps within the study include sourcing of raw materials, specific aging of wine grapes, and other winery creation decisions. Future studies using comprehensive data for the Central Coast will best help to recommend strategies to improve the sustainability of the industry.

Acknowledgements

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