Improving Decision-Making Toward Sustainability

Life Cycle Assessment a Multivariable Approach to a Sustainable Wine Scoring System

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Andres Eduardo Valero is an engineer who holds a Master of Science in Environmental and Ecological Engineering from Purdue University (Indiana) and an Industrial Engineering degree from the National University of Cuyo (Mendoza, Argentina). At Purdue, after receiving an Argentinean Presidential Fellowship by Fulbright and an OIV research grant, Valero conducted research on the usage of life cycle assessment and environmental footprints as a strategy to achieve long-term sustainability in the wine sector. Currently, Andres collaborates with wineries, such as Grupo Peñaflor, with their environmental and quality management systems.

SUSTAINABILITY IS BECOMING a core value for the wine sector world-wide. Sustainable practices are recognized by a large part of the wine community as a necessary step to face climate change challenges and natural resources depletion[1]. In recent years, sustainability has had a growing influence on the consumer's decision.

Nonetheless, when looking at the sustainable attributes of a bottle of wine, consumers face numerous obstacles. Despite consumers appreciating "sustainable wine," evidence suggests that they do not fully understand the practices a winery must follow to be cataloged as sustainable. The willingness to pay more for wine's sustainable attributes is limited due to the lack of familiarity with the meaning behind the more than 300 eco-labels claiming to be sustainable[2]. Moreover, grape growers and winemakers find it challenging to quantify which will be the improvement of their sustainability profile when following a specific sustainable practice or program in comparison with the costs associated with its implementation and the potential return on investment.

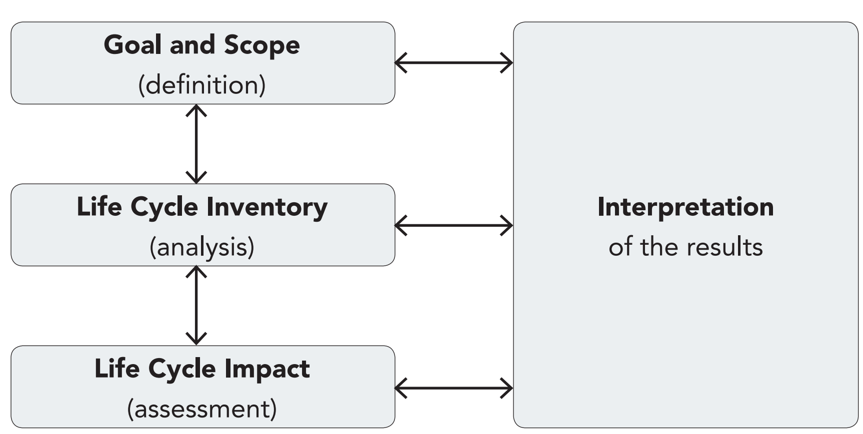
Implementation of sustainable principles to a specific economic sector requires expanding vision beyond traditional boundaries of the sector. There is a need to migrate to a business structure that looks to minimize the environmental impacts, during the whole life cycle of wine, while enhancing the social and economic performance of the organizations and stakeholders involved. Therefore, to turn a concept, such as sustainability, into effective actions we should use tools that allow us to quantify impacts.

Life Cycle Assessment as a Tool to Quantify Environmental Sustainability

Life Cycle Assessment (LCA) is a methodology that can support decision making regarding sustainability while facilitating communication. LCA is an internationally recognized standardized method to characterize and quantify the environmental impact. Understanding the impact of a product over the entire life cycle guides decisions to improve the sustainability of producing wine without creating unexpected or unintended consequences on the environment—or at least understanding the trade-off involved.

LCA can be adapted to define baselines for regional sustainability and define realistic and achievable goals. The ISO 14040/44 families provide the basis for LCA. The ISO 14040 standard provides the principles, framework and limitations of the method[3]. The ISO 14044 standard provides the requirements and guidelines for preparing, conducting, reviewing and interpreting an LCA[4]. The standards recognize that an LCA study should include four phases: a goal and scope definition, an inventory analysis, an impact assessment and interpretation of the results (FIGURE 1).

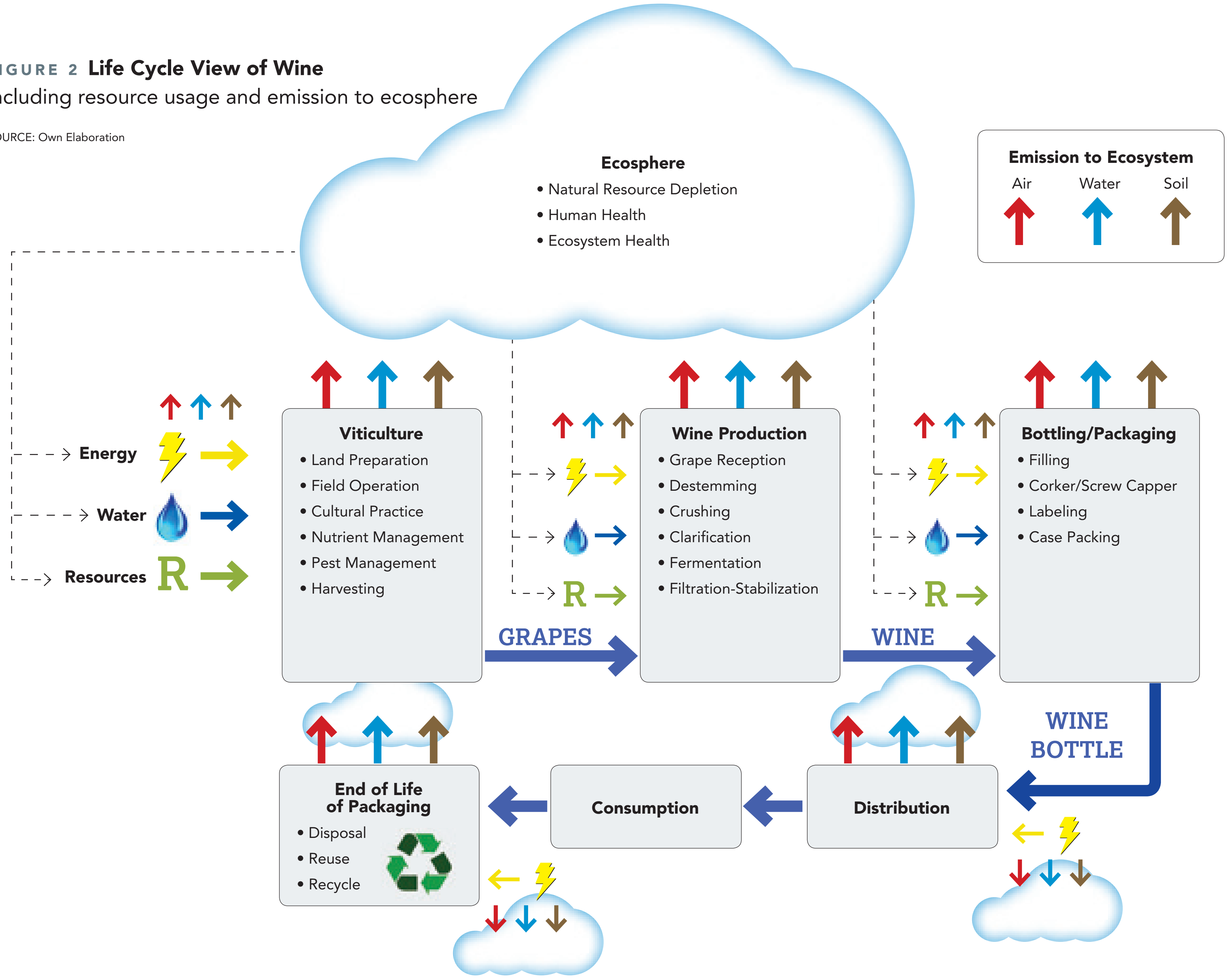
FIGURE 1 Life Cycle Assessment Framework



SOURCES: Figure adapted from ISO 14040:2016 [3]

FIGURE 2 Life Cycle View of Wine
including resource usage and emission to ecosphere

SOURCE: Own Elaboration



LCA allows quantifying interactions between the ecosphere and all the activities required for getting wine into the consumers' glasses (FIGURE 2). The interaction (including the extraction of resources from Earth and the emission of different substances into the atmosphere, soil or water bodies) is translated into the different mechanisms (cause-effect chain) of impact to human health, ecosystem services and/or natural resources availability. LCA also contributes to identify hotspots on the supply chain and helps us to evaluate how implementing different strategies in our supply chain will modify environmental performance.

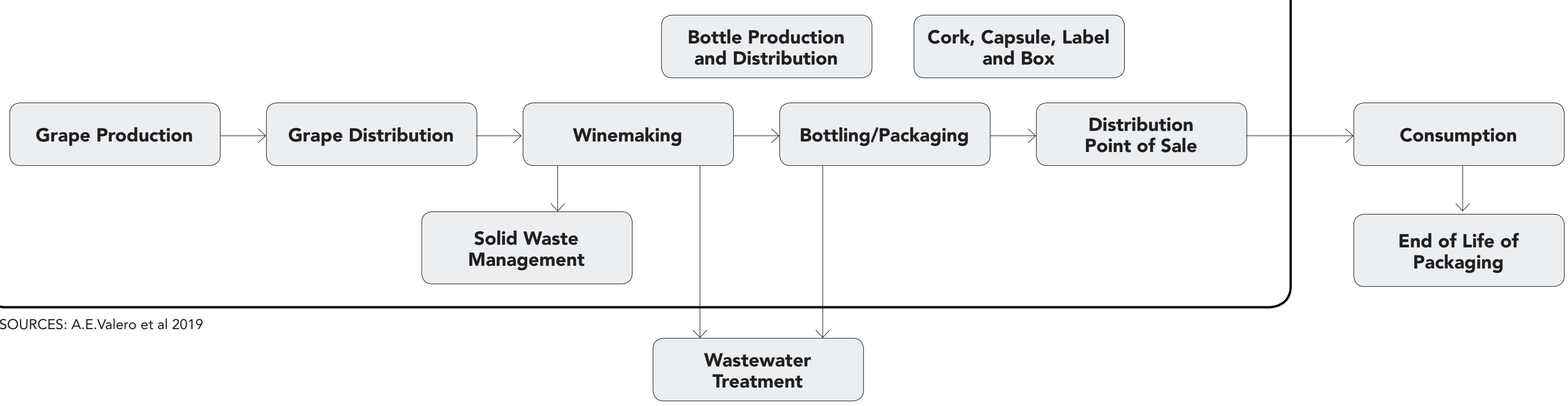
Indiana Case Study and Development of Sustainable Wine Scoring System

Below is a case study of the application of a multi-variable LCA for a wine region and our initial approach to defining a **Sustainable Wine Scoring System** (SWSS). This research was funded by the **International Organisation of Vine and Wine** (OIV)* and developed at the **Environmental and Ecological Engineering** (EEE) division at **Purdue University**. The SWSS aims to be a single numeric index of the sustainability attributes of a bottle of wine based on multiple normalized indicators[5]. This initial approach to define an SWSS focuses on environmental sustainability.

Goal and scope definition is the first phase of an LCA study that follows the ISO 14040/44 standard. This phase aims to identify the purpose of the LCA study, its application and target audience. The goal of our research is to quantify environmental impacts and identify improvements in the life cycle of "craft wine" made and consumed in Indiana, representing an emerging non-traditional wine region in the United States. Additionally, this phase includes the definition of the functional unit (FU) and system boundary (SB). The FU is the reference value on which the result of the impact will be presented. The SB includes all the assumptions, limitations, data requirements, and allocation criteria. The SB delimits the stages (unit process) necessary to produce the FU. For our study, we define FU as a bottle of red dry wine (750ml) sold in Indiana, and our SB includes the agricultural phase (grape production), industrial phase (winemaking, wine bottling and solid waste management), primary and secondary packaging, manufacturing and distribution of wine to the point of sale (FIGURE 3).

The **Life Cycle Inventory** (LCI) consists of the systematic data collection and modeling of the flow of material, energy and emission for each stage within the SB necessary for producing an FU. We collect and quantify all the input necessary for each unit of the process and all the output generated. For example, during the de-stemming and crushing process, we have inputs, including the grapes, enological supplies, the energy, water use for different purposes (cooling, cleaning, etc.), and output as grape must, stems and wastewater.

FIGURE 3 System Boundary of Our LCA Study[5]



SOURCES: A.E.Valero et al 2019

During the **Life Cycle Impact Assessment** (LCIA) phase, the substances identified during the LCI are grouped according to the mechanism of impact to the environment they are potentially involved in. The results of the LCI are grouped into impact categories according to the potential damage to human health, ecosystem services and natural resources availability. For example, each gas released into the atmosphere, during the different production stages, that can harm the ozone layer will be grouped in the ozone depletion potential impact category while the gases that can contribute to the greenhouse effect will be grouped in the global warming potential impact category.

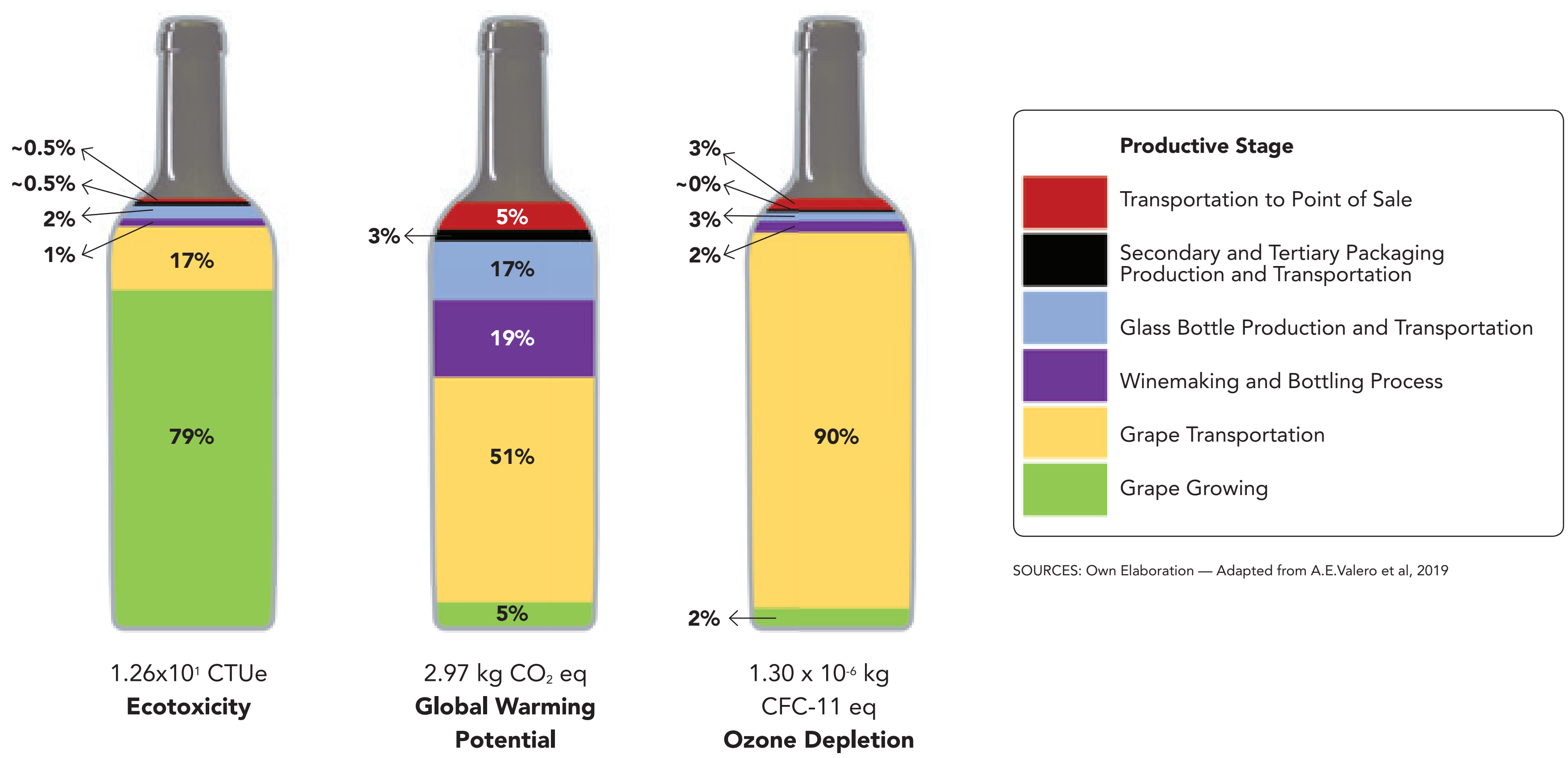
Each substance within the same impact category is multiplied by a characterization factor. The characterization factor quantifies the relative contribution of that substance to the category, allowing us to add all the relative effects of the substance into one indicator. For this case, we conduct the LCIA using **SimaPro 8.5** software in accordance with the **Tool for Reduction and Assessment of Chemical and other Environmental Impact**"(TRACI 2.1/USA:2008) developed by the **United States Environmental Protection Agency**[6,7]. TRACI defines 10 impact categories that describe the potential damage to human health, ecosystem services and natural resource depletion, including "ozone depletion," "global warming," "smog," "acidification," "eutrophication," "human health carcinogenic," "human health non-carcinogenic," "respiratory effects," "ecotoxicity" and "fossil fuel depletion." For more details about these impact categories and TRACI visit *epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci*

Analysis of Results

Our reference scenario (IW1) consists of wine made and distributed in Indiana, made with grapes grown in California and bottled in a glass bottle produced in the United States. On one hand, grape growing is the major contributor to impact, including human health (non-carcinogenic and carcinogenic), ecotoxicity and eutrophication due to the emissions related to fertilizer, pesticide and herbicide usage.

On the other hand, grape transportation is the primary contributor to impact categories related to atmospheric contamination, such as ozone depletion, global warming, smog, acidification and respiratory effect. Manufacturing of the glass bottle is the second or third contributor to all the impacts, with a higher contribution to human health-carcinogenic, acidification, global warming and respiratory effect (FIGURE 4).

FIGURE 4 Relative contribution of a FU of IW1 for each productive stage for 3 of the 10 impact categories[5]



SOURCES: Own Elaboration — Adapted from A.E.Valero et al, 2019

NAPA VALLEY
EST. 1975
GRAPEGROWERS

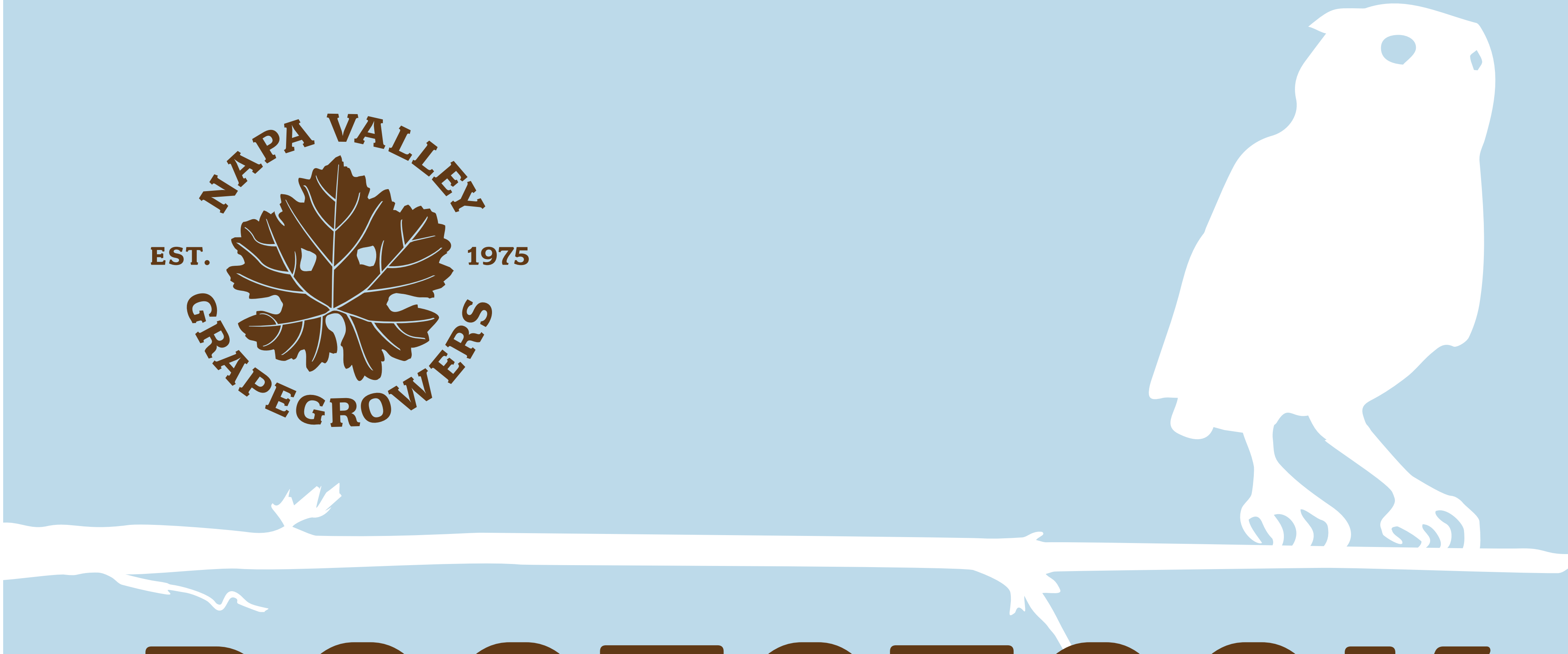


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TABLE 1 Description: Supply Chain Scenarios [5]

Scenario	Supply Chain Description	Wine Production	Grape Origin	Glass Bottle Manufacturing Origin	Energy Grid Type	Final Product Distribution
Initial Scenario	IW1	Indiana	California	USA	Indiana	Indiana
	CW1	California	California	USA	California	Indiana
Alternative Bottle Supply	IW2	Indiana	California	CHINA	Indiana	Indiana
	CW2	California	California	CHINA	California	Indiana
Grape Juice Must	IW3	Indiana	California	USA	Indiana	Indiana
Alternative Grid Characteristics	IW4	Indiana	Midwest	USA	Cleaner Grid	Indiana
Alternative Grape Supply (local)	IW5	Indiana	Midwest	USA	Indiana	Indiana

Sources: A.E.Valero et al 2019

We define alternative scenarios (**TABLE 1**) to evaluate how changes in the supply chain modify the impact of the production of the FU. When glass bottles are sourced from China instead of the United States (IW2), the impact increases for all categories. For scenarios in which grapes or must need refrigerated transportation (IW1, IW2 and IW4), ozone depletion is more than four times higher in comparison to other scenarios. In the same manner, these three scenarios almost double IW3 and IW5 regarding global warming potential.

The differences among the lower impact scenario and the higher impact scenario for both smog and fossil fuel depletion categories reach 60 percent. Ecotoxicity and non-carcinogenic are the indicators that showed less dispersion on the values among the different scenarios. The best performance for all the categories, except carcinogenic, is from IW5, the supply chain in which grapes were procured from areas in the Midwest of the United States (**TABLE 2**).

Changes in one material or process are likely to have a positive impact on one category while having a neutral or even negative effect on others. We evaluate the effects on environmental performance when reducing 5 percent and 35 percent of the glass bottle weight for IW1 and CW1, respectively (**TABLE 3**). For IW1, the impact of higher improvement is achieved for the carcinogenic while the improvement on ecotoxicity, non-caarcinoogenic and ozone depletion are 1 percent for a 35 percent reduction. The average impact

TABLE 2 Percent variation of impact regarding IW1 for different supply chain scenarios[5]

Impact Increase | IW1 | Impact Reduction

Impact\Scenario	IW2	IW3	IW4	IW5	CW1	CW2
Ozone depletion	0%	-82%	-1%	-90%	-77%	-77%
Global warming	6%	-37%	-10%	-48%	-42%	-39%
Smog	39%	-38%	-7%	-53%	-26%	-9%
Acidification	20%	-26%	-15%	-36%	-34%	-25%
Eutrophication	5%	-12%	-5%	-16%	-16%	-14%
Carcinogenic	18%	-4%	-9%	0%	-16%	-8%
Non-carcinogenic	2%	-5%	-2%	-9%	-8%	-7%
Respiratory effects	4%	-22%	-9%	-41%	-23%	-21%
Ecotoxicity	4%	-7%	0%	-15%	-7%	-5%
Fossil fuel depletion	7%	-43%	5%	-59%	-30%	-27%

SOURCES: A.E.Valero et al, 2019

TABLE 3 Percental variation in impact categories when variating glass bottle weight for IW1 and CW1

	IW1		CW1	
Bottle Weight Reduction	-5%	-35%	-5%	-35%
Ozone depletion	0%	-1%	-2%	-11%
Global warming	-1%	-6%	-2%	-14%
Smog	-1%	-6%	-2%	-13%
Acification	-1%	-9%	-3%	-16%
Eutrophication	0%	-2%	-1%	-3%
Carcinogenics	-2%	-12%	-2%	-14%
Non carcinogenics	0%	-1%	0%	-2%
Respiratory effects	-1%	-9%	-2%	-14%
Ecotoxicity	0%	-1%	0%	-2%
Fossil fuel depletion	-1%	-8%	-2%	-14%

SOURCES: Own Elaboration

The average glass bottle (750ml) consider weighted 505g, 5% reduction represents bottles of 475g and 35% represent a glass bottle of 325g (one of the lighter bottles available in the market).

improvement is 5 percent for the 35 percent weight reduction. For CW1 the average impact improvement is 10 percent for the 35 percent weight reduction. The higher improvement is achieved for the acidification impact followed by a notable improvement in most of the other events, except eutrophication, non-carcinogenic and ecotoxicity.

SWSS Development and Communication

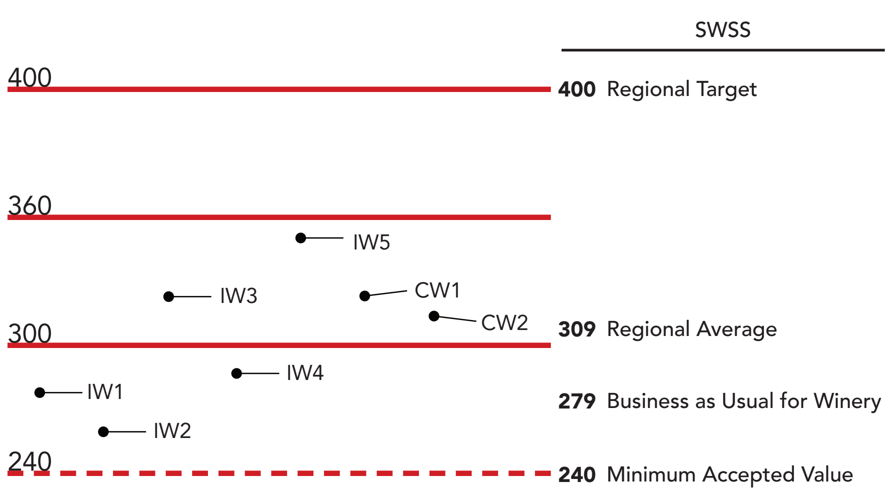
Communicating internally or externally, the result of each impact categories to a non-expert audience can be complex; therefore the SWSS is a simplified tool that can help us. Calculated based on the sum of the normalized values for the 10 impact categories evaluated, **FIGURE 5** shows the resulting SWSS for each scenario. The SWSS allows us to define a baseline or minimum accepted environmental sustainability profile, according to accepted practice on the supply chain.

We can define the average value for the business as a usual value for the region. We can define a reasonable science base and achievable target for sustainability within a region. With this tool, we can evaluate the cost of implementation of different sustainable practices and their impacts on the environmental profile, allowing us to optimize our budget to achieve better performance or improvement.

FIGURE 5 Example of Sustainable Wine Scoring System® (SWSS) as a regional framework for sustainability

$$SWSS_s = \frac{1}{\sum_z^1 Ns_z W_z}$$

Scenario	SWSS
IW1	279
IW2	259
IW3	322
IW4	287
IW5	351
CW1	322
CW2	313



SOURCE: Own Elaboration, variables Nsz and Wz, Source A.E.Valero et al 2019

Conclusion

Each wine region has a unique ecosystem that is reflected in the identity of their products. The different elements involved in winemaking in each region need the proper base of information to define their own strategies to achieve their best performance regarding environmental sustainability according to the resources available. Rethinking the wine business through incorporation of a Life Cycle Assessment contributes to decision-making toward sustainability for all size organizations within the wine sector.

The proposed Sustainable Wine Scoring System serves as an example of how the information generated during an LCA study can be used as a tool for decision-making toward sustainability to set achievable numeric targets, while improving how we communicate our sustainability profile to our customers and consumers. WBM

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* International Organisation of Vine and Wine (OIV) http://www.oiv.int