Circular business models and packaging through the supply chain: a Chilean wine industry case study

Master's Thesis – Sustainable Business and Innovation

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Abstract

Chile has shown the ambition to position itself as a leader in producing sustainable wines. A National Sustainability Code and the Extended Producer Responsibility (EPR) law were implemented in the last two decades. However, none of them properly addresses the waste generation for packaging trough the supply chain. Circular business models (CBMs) have been studied as a possibility to reduce waste generation. This research aims to study the amount of packaging waste generation that CBMs can reduce through the supply chain.

To quantify packaging trough the supply chain, primary, secondary and tertiary packaging were studied using a Material Flow Analysis. Two systems were defined and compared to calculate the potential waste reduction; a system representing the current state, and a new theoretical configuration where CBMs are in place. The current system was defined by collecting data from experts' interviews, company reports and governmental publications. The new configuration was devised using the retention options hierarchy framework, combined with industry best practices and in-depth assessment with industry experts.

The selected primary packaging was glass bottles which generated 70.089 ton of waste and it was reduced to 14.950 ton by incorporating the CBM 'deposit-refund services'. The secondary packaging studied was cardboard boxes which generate 3.695 ton of waste per year, the new design considered increasing the recycling rate which could reduce waste to 1.852 ton. For tertiary packaging two materials were selected, wood and plastic pallets. Wood pallets generate 15.826 ton of waste and plastic pallets do not because their model is already circular. Pallets' waste was reduced to cero by incorporating the CBM 'transport & logistics services'. The total waste that CBM could reduce is 81% from 89.610 to 16.747 ton per year which is mainly explained by increasing the returnability of glass bottles and pallets by seven times.

The results show that there are multiple gaps that along the packaging process where CBMs could be effectively applied to reduce waste generation on the packaging of the domestic Chilean Wine. This was a theoretical study; therefore, prototypes and specifics studies are advised before implementing one of the activities or CBM found in this research.

Acronyms

ANIR	Asociación Nacional de la Industria Del Reciclaje (National Association of the Recycling Industry)
CBM	Circular Business Model
CE	Circular Economy
CENEM	Centro de Envases y Embalajes de Chile (Centre of Containers and Packaging of Chile)
CONICYT	Comisión Nacional de Investigación Científica y Tecnológica (National Commission for Scientific and Technological Research)
EPR	Extended Producer Responsibility
FSC	Forest Stewardship Council
IRP	International Resource Panel
MFA	Material Flow Analysis
ODEPA	Oficina de Estudios y Políticas Agrarias (Office of Agricultural Studies and Policies)
OECD	Organisation for Economic Co-operation and Development
OIV	International Organisation of Vine and Wine
PEFC	Programme for the Endorsement of Forest Certification
PET	Polyethene terephthalate
PP	Polypropylene
PRC	People's Republic of China
RO	Retention Option
SAG	Servicio Agrícola y Ganadero (Agricultural and Livestock Service)
SUBDERE	Subsecretaría de Desarrollo Regional y Administrativo (Regional and Administrative Development Under secretariat)
UN	United Nations
UNEP	United Nations Environment Programme
WPO	World Packaging Organization

Format

Numbers

","	decimal separator
"."	thousands separator

Colour code

	Green	Glass bottle
	Brown	Cardboard box
	Grey	Wood pallet
	Sky-blue	Plastic pallet

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1 Introduction

Since the industrial revolution, human actions have pushed the environmental state out of its equilibrium, with potentially catastrophic consequences for long-term social and economic development (Lenton et al., 2019; Rockström et al., 2009; Steffen et al., 2015). For the past century, the predilect business model has been linear one known as the 'take-make-dispose' within an industrial system that relies largely on fossil fuels (Bocken, Bakker, & de Pauw, 2018; Geisendorf & Pietrulla, 2018). We are now starting the 4th industrial revolution, characterized by an increase in connectivity and flow between people, products and systems that integrate technology to create smarter economic growth (Kobza & Schuster, 2016). It is in this context, coupled with increased consumption and resource scarcity, that the idea of a circular economy (CE) rises; which is understood as a regenerative system where resource input and waste, emission and energy leakage are minimised by slowing, narrowing and closing the resources loops (Geisendorf & Pietrulla, 2018; Geissdoerfer, Savaget, Bocken, & Erik Jan, 2017; Kirchherr, Reike, & Hekkert, 2017; Reike, Vermeulen, & Witjes, 2018).

For companies, the adoption of circular business models (CBMs) become relevant as studies show benefits such as material savings, reduced supply risks, improved customer loyalty and development of new revenue streams (De los Rios & Charnley, 2017; Schenkel, Caniëls, Krikke, & Van Der Laan, 2015; Winkler, 2011). However, to improve circularity, companies require to implement changes in the way they understand and do business to create value. Innovation in their business model can be a struggle for established companies as it often conflicts with their prevailing strategy or with the underlying configuration of assets that support that prevailing model (Chesbrough, 2010).

In a globalized society, products and materials come from all over the world, thus governments and organizations are increasingly incorporating circular requirements in their procurement procedures to promote closing energy and material loops within the supply chain[1] (UNEP, 2018). Countries that are pioneers in the incorporation of CE strategies are the EU (European Commission, 2015), Japan and China (PRC, 2008) as they seek to reduce the dependence on imported raw materials and pressure on domestic resources (Ogunmakinde, 2019). The transition towards CE is not the responsibility of a single-player as it involves economic and societal stakeholders in the supply chain that need to collaborate to facilitate closing-the-loop of resources (Geng, Fu, Sarkis, & Xue, 2012).

High income and developing countries should work differently towards achieving CE as the biggest driver of resource consumption is not population growth but consumption patterns; high-income countries use over 10 times more resources per capita than developing countries (Potocnik, McGinty, & Gawel, 2019). The International Resource Panel (2019) advise high-income countries to absolute decouple to lower average resource consumption and to developing countries to relative decouple to raise average income levels and eliminate poverty, while still increasing levels of natural resource consumption until a socially acceptable quality of life is achieved.

Most of the research about CE has been done in developed countries, mainly in USA, Australia, Japan and the EU, and in the developing country of China (Homrich, Galvão, Abadia, & Carvalho, 2018). Current research is inclined towards theoretical and conceptual analysis, several important questions remain which may be better answered via context-specific case studies (Ernst & Young,

[1] See section 3.3 for a clearer definition for value chain and supply chain.

2016). Thus, more context-specific and focused on the entire supply chain studies are needed, specifically on developing countries or regions characterized as resource suppliers (Levänen, Lyytinen, & Gatica, 2018).

Latin America is a major resource exporter, therefore has an important role in the global transition to a circular economy (West & Schandl, 2013). The circular economy exists as isolated activities in the region and a new system-wide, multi-stakeholder approach will be essential to bring them to scale. We believe that Chile, the first country from Latin America that entered the Organisation for Economic Co-operation and Development (OECD), is an interesting case study, as it has declared as one of their main goals their ambition to become more circular. Moreover, the last version of the Forum on Circular Economy for Latin America was headquartered in Chile, where one of the main objectives was to build the CE strategic roadmap for Chile (fEC, 2018).

Chile is also a leading country on wine exports among the new world wine countries and it is positioned as the fourth main wine exporter worldwide (OIV, 2019). Therefore, a voluntary national sustainability code was created to improve the Chilean wine industry image towards sustainability, which has had a great uptake among Chilean wineries (Foods From Chile, 2019). Surprisingly, this certification does not include packaging in the supply chain of wine (Vinos de Chile, 2015b), even though it is considered by some authors as the process with the biggest carbon footprint in the wine industry (Pattara, Raggi, & Cichelli, 2012). On general terms, research states that packaging's environmental impact is largely due to its relatively short lifetime and that the amount of waste it generates approximately equals the amount of packaging created on the market, thus there is a big potential to close the material flows of it (Huang & Ma, 2004).

The focus of the supply chain is the product itself, therefore is not unusual that the wine packaging has been neglected as a sustainability focus, and the principal concern for packaging is to just deliver the product safely through the supply chain (Emblem, 2012). From this linear business model, packaging becomes a temporary by-product that becomes waste after a single-use. This means that wineries that want to become circular, need to implement reverse and sideways logistics systems (Lewandowski, 2016; Weetman, 2016). Moreover, there is not only a need for change downstream activities but also upstream activities by incorporating recycled and renewable raw materials in the design of the packaging (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Ogunmakinde, 2019).

1.1 Problem definition

Chile has shown the ambition to position itself as a leader in producing sustainable wines, and even though great improvements have been made, there is still a lack of more specific and scientific-based studies. There is a knowledge gap related to the extent of waste produced due to wine packaging and at what extent circular initiatives could reduce it. If this gap is not addressed, the Chilean wine industry may fail to become the leader in sustainability. The linear model of packaging is responsible for high economic, social and environmental impacts, changing it to a circular one has the potential to reduce the generation of waste.

1.2 Research objective

In this research, we want to study quantitatively to what extent circular business models can reduce the waste generated from packaging through the supply chain, by studying the case of the Chilean wine industry in the domestic market. For this reason, we are going to answer the following questions:

1.3 Research questions

To what extent circular business models can decrease the waste generated from packaging in the Chilean wine supply chain for its domestic market?

To provide context and assess the impact we will first address the following sub-questions:

1. *What is the current amount of waste generated from the packaging?*
   By answering this sub-research question, we will understand the set of activities, the input of raw materials, the flow of goods and waste generated within the Chilean wine industry to deliver their product. Additionally, we will get insights into the current circular activities within this sector.

2. *How can circular business models affect the configuration of the supply chain?*
   By answering this question, we will understand how other industries 'and international' higher value retention options may have an impact across the process and loops of the supply chain, making it more circular. To answer this sub-question, we will devise a new configuration for a circular supply chain.

3. *What would be the amount of waste generated considering the new circular supply chain configuration?*
   Here, we will comprehend the description of the flow of raw materials, products and waste generated for the new system proposed. This will allow us to compare it with the current system and understand to what extent could the waste generation be decreased.

1.4 Research relevance

The scientific relevance is to understand how a generic theory can be applied to a case study, and which adjustments had to be made to the theory to make it applicable to this case.

The societal relevance is to find specific circular strategies for the Chilean wine industry that could be implemented and improve the environmental performance of the packaging in the wine industry by reducing waste generation. Also, it would give more data and tools to the members of the supply chain to make changes in a scientific-based way.

1.5 Document structure

This document has a total of seven chapters which are: Chapter 1 consists of an introduction based on a general review of the main concepts and establishes the field of our research, it also shows the literature gap and consequently the purpose and questions for this research. Chapter 2 contains background information about the study case, describes the Chilean wine industry including its sustainability performance and general packaging process used in the industry. Also, here it is included a revision of CBMs and practices related to CE relevant for the case study. Chapter 3 describes the main definitions and theories of CE used to establish an analytical framework that suits to the study case. Chapter 4 corresponds to the methodology and research design, which is divided into three parts answering each sub research question, it explains the techniques used to collect and sample data, as well as, the procedures used to analyse the gathered information. Chapter 5 illustrates the results of the research, where the current packaging system and flows are shown. The waste generated for each stream, and the ability of CBMs to reduce these waste streams are also displayed. Chapter 6 includes a discussion of results and relates them with the research question and previous research. Chapter 7 presents the conclusion of this research.

2 Background: Wine industry and circular economy in Chile

This section shows antecedents about the Chilean wine sector and its sustainability performance with a description of the packaging process; it presents some statistics about the Chilean wine industry and the sustainability approach of the sector, as well as a description of the packaging for wine in general. Also, it reports the current practices regarding circular business models and circular practices.

2.1 The wine industry in Chile

By the end of 2017, the total surface of wine grape growing farms in Chile reached 135.908 hectares located mainly in the central regions of Chile (Figure 2.1).

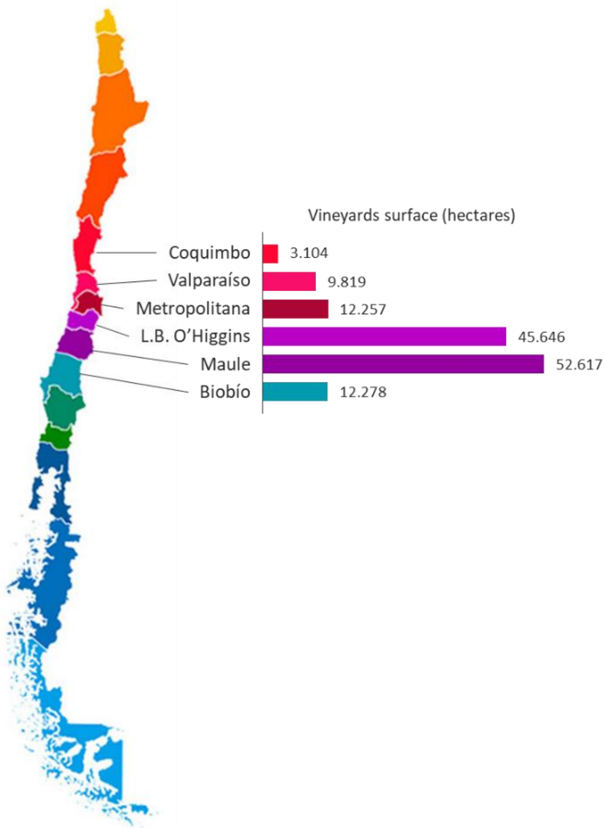

Figure 2.1: Surface of vineyards planted in Chile; own elaboration based on ODEPA (2019)

The strategy of the Chilean leading companies has been to focus on high-quality wines to increase the price, in consequence, reduce risk due to fluctuation in volume production (CENEM, 2018). Wine producers have taken advantage of the climate and soil conditions found in the grape-growing valleys of Chile; and they have also selected the right varieties for each region, guided by the professional work of specialists (CONICYT, 2007). Chile has been noticeably turning its wine production towards Denomination of Origin (DO) wines, which have become the base of the industry with a production of 10,3 million hectolitres in 2019 representing the 84% of the total production (Figure 2.2). The price per litre of Chilean wines with DO is around 3 times higher than the ones without DO (ODEPA, 2020). For these wines, brand recognition is a key attribute, and thus, it is usually exported bottled. On the other hand, wines without DO usually compete on price, and its exported in bulk, bottled and branded in the country of destiny before the end customer commercialization.

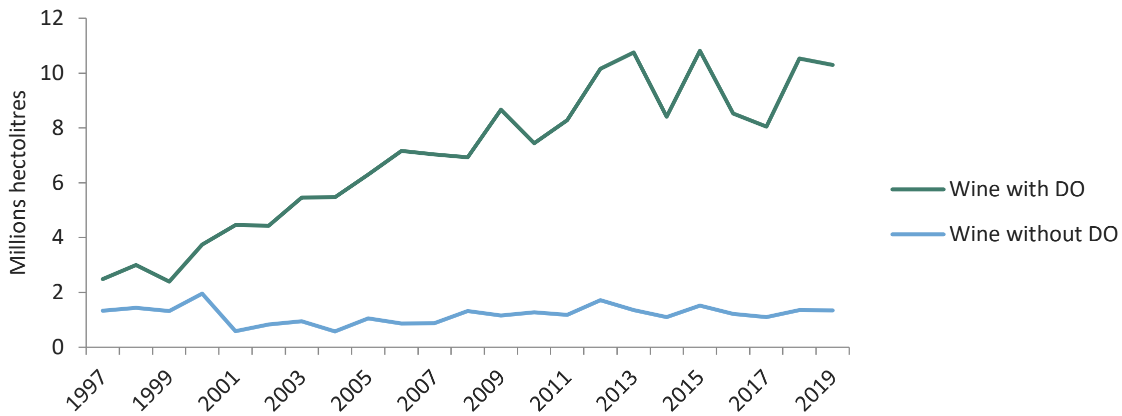

Figure 2.2: Chilean wine production trend per type; own elaboration based on ODEPA (2020)

Among the new world wine countries, Chile is leading on exports, as it promotes international trade by being one of the most open markets (CONICYT, 2007); which has resulted on positioning Chile as the fourth main wine exporter in volume worldwide (Figure 2.3). Chilean wine production is exported to 150 countries and consumed for more than 1.800 million people in the world (Foods From Chile, 2019). In 2018, Chile exported 9,3 million hectolitres of wine ranking fourth in the world with a total production of 12,9 million hectolitres (OIV, 2019). Currently, Chile positions itself as the principal supplier for bulk wine in China and bottled wine in Europe (ProChile, 2018). In 2018, Chile exported more than 50 million boxes of bottled wine representing 457 million litres evaluated in US$ 1.508 Million, and 356 million litres of bulk wine evaluated in US$ 359 million (ODEPA, 2020).

Figure 2.3: Main wine exporters countries; own elaboration based on OIV (2019)

Although Chilean wine exports represent more than 60% of total production, the domestic market is still the biggest one in terms of volume (Foods From Chile, 2019). This is an interesting phenomenon, explained mostly because exports are spread out in several countries, and within the domestic market, there is little competition from other countries, as the imports are less than 1% (ODEPA, 2020). However, yearly per capita consumption is relatively low with only 18,1 L per capita compared with France where consumption is 46,4 L per capita (Wines of Chile, 2019). Figure 2.4 illustrates the market share in volume for the Chilean wine sells of its bottled or DO wines for 2018.

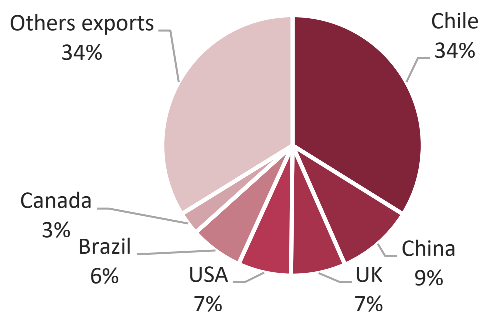

Figure 2.4: Chilean wine market share sells; own elaboration based on ODEPA (2020) and Wines of Chile (2019)

2.1.1 Sustainability

The non-profit and private union representing Chilean winemakers, Wines of Chile, was created in 2007 to join the two existing unions at that moment: Viñas de Chile A.G. and ChileVid A.G. (Foods From Chile, 2019). The main strategy of Wines of Chile is to position Chilean wines as premium, diverse, and sustainable in an international context, dividing their line of action in four pillars: diversity quality, sustainability, country image and innovation (Wines of Chile, n.d.).

Within this organization, a voluntary National Sustainability Code was created which aims to incorporate sustainable practices in wine companies. The objective is to promote the benefits of sustainable production of high-quality wines by motivating grape producers and winemakers to improve their management through compliance with the requirements established in the standard specified within the code (Vinos de Chile, 2015a). The Code establishes the requirements in three main areas of the production chain, which have been identified according to the context of the Chilean wine sector (Figure 2.5). These three areas are 'Vineyard', which includes own field and long-term suppliers, 'Winery' which contemplates also bottling plant and other facilities related to wine production, and 'Social' that includes its fields, offices and facilities.

Figure 2.5: Three areas of the National Sustainability Code; extracted from www.sustentavid.org

By 2019, the number of certified wineries reached 77, representing more than 70% of the total exportations (Foods From Chile, 2019; Vinos de Chile, 2019). The certification has been recognized by important supermarkets and alcohol monopolies, such as Systembolaget, Vinmonopolet, SAQ and Mark & Spencer. The certified wineries can use the trademark and logo of 'Certified Sustainable Wine of Chile' (Figure 2.6), to be easily recognizable as a sustainable wine.

Figure 2.6: Logo of the National Sustainability Code; extracted from www.sustentavid.org

The certification has a triple bottom line focus, being one of the clearest to incorporate all three components of sustainability and not only an environmental improvement (Moscovici & Reed, 2018). However, a limitation of the certification is that it does not include packaging, and most members through the wine supply chain; focus their efforts on the product itself, vineyards and internal wineries processes (Vinos de Chile, 2015b). Therefore, there is a lack of a circular perspective of the entire supply chain, for packaging.

2.1.2 Wine packaging

The wine packaging is characterized for flowing through the supply chain from its production to the end consumer. Packaging, in general, can be classified depending on the function that it fulfils in the supply chain: Primary, secondary and tertiary. Primary packaging of wine (i.e. bottle and label) is designed to engage the customer, increase perceived value and as an outcome, improve the likelihood of purchase and revenue (Barber, 2010). Thus, innovations for more sustainable packaging has not been massively adopted due to a perception that customers recognise the glass bottle's substitutions as lower-quality (Cooper, 2019).

On the other hand, secondary (i.e. card-box) and tertiary (i.e. pallet and wrap or tank) packaging, are key to provide protection and avoid damage to the product during transportation and storage. Secondary packaging mostly consists of a card-box of 12 or 6 bottles, being on the rise the 6 bottle pack as end-consumers are starting to change their purchase patterns buying on packs; a direct consequence of this relates to an increase in the amount of material used (Cholette & Venkat, 2009).

Wood or plastic pallets are the most common type of tertiary packaging in the wine industry. Pallets are used along with stretch wrap film and a label, to secure the secondary packing to the pallet and provide a ready means of identification (Emblem, 2012). Flexitanks or ISO tanks are also considered tertiary packaging. These tanks carry bulk wine for exports and then later is bottled in the country of destiny. This option has been used because it has smaller GHG emissions than the bottled trade wine (CBI Market Intelligence, 2016). Although there is also a slow take-off due to the relation of poor-quality wines with the bulk trade.

In Chile, the glass-packaging market is concentrated in four glassmaking companies. CristalChile is the biggest representing 62% of the total market, Verallia (former Saint-Gobain) has 25%, ‘Cristalerías Toro’ represents 10% and Favima 3%. From these companies, only the top three sell wine bottles ((Represented with the icon in Figure 2.7).

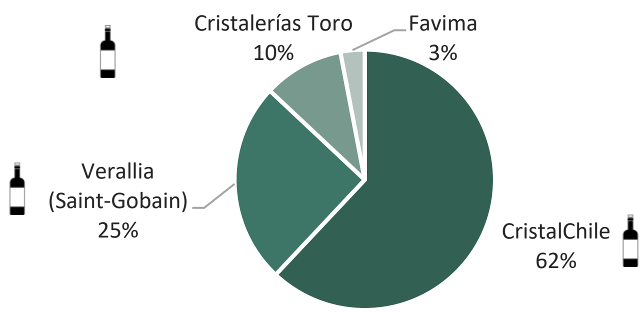

Figure 2.7: Market share for glass packaging manufacturers; Own elaboration based on CyV Medioambiente (2010)

Chile’s cardboard market is less concentrated than the glassmaking, but still, there are only eight suppliers of corrugated paper which have more than 90% of the market, ‘Envases Impresos’ (CMPC group) represents 45%, followed by ‘International Paper’ and ‘Cartones San Fernando’ both with 10%, Cartocor with 8% and ‘Smurfit Kappa’, Imicar, Corrupac, Chilempack with 5% (Figure 2.8). As far as we are concerned, only five of these companies advertise products for the wine industry (Represented with the icon in Figure 2.8).

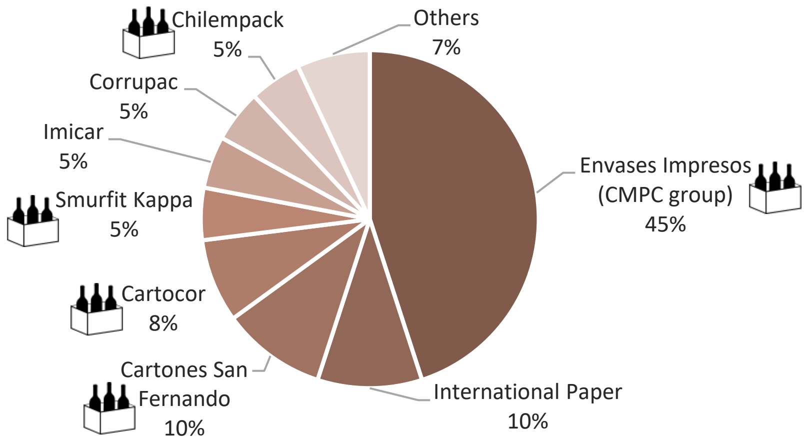

Figure 2.8: Market share for corrugated cardboard paper manufacturers; Own elaboration based on CyV Medioambiente (2010)

The author was not able to find aggregated public information concerning active companies in the Chilean pallets´ market.

2.2 Circular Economy in Chile

The Chilean Ministry of Environment oversees the Circular Economy Office, which aims to reduce the environmental impact related to waste generation. They propose a change from a linear production, business and consumption system to one that incorporates the concepts of eco-design, reuse, recycling and recovery (Ministerio del Medio Ambiente, n.d.). On this context, Chile introduced the concept of Extended Producer Responsibility (EPR) in the waste management system. This concept was developed in Europe during the 90s with positive results, thus encouraging replication in other countries and waste streams. EPR means that a producer (or importer) must take charge, or be at least co-responsible, of a product´s waste once its useful life has ended (CyV Medioambiente, 2010). On 2016, the EPR law was issued which introduced, the concept of waste treatment hierarchy where the preferred solution is the prevention, followed by reuse, recycling of the entire product or parts of it, and finally, recovery of energy. It also incorporates the use of tools to achieve circularity, such as eco-design, certifications or labels, and deposit-refund systems (Ley 20920, 2016). This law works as a framework that defines and regulates six prioritized products; where 'packaging' is defined as one of them. At the moment, there is a proposed draft for the goals and obligations for packaging (Resolución 544 Exenta, 2019) and its the deposit-refund system in (Resolución 1492 Exenta, 2018).

This office is also leading the elaboration of the Circular Economy Roadmap at a country level. This will be a long-term planning instrument, which has been used by most countries that are at the forefront of achieving circularity. This initiative was launched on December 2018 during the Latin American Forum of Circular Economy, with a participative approach that connected key actors to make a diagnosis of the current situation, define ambitious goals and design a strategy to achieve them (Molina Alomar, 2018). Recently, a roadmap was defined that follows a transversal and non-sectoral approach, based on three areas: sustainable production, sustainable consumption and waste management; with evaluation horizons in 2030 and 2040 (Molina Alomar, 2020). The firsts two topics to be addressed are the low cost associated with the disposal of waste in sanitary landfills and the role of producing energy from waste. The final objective is to reduce the waste that goes to landfill to only 10% by 2040; nowadays, more than 96% ends in a landfill (SIGA, 2018).

For the agri-food sector, there is a specific study on CE which has as objective to understand the state of the art of CE policies in the sector and its sub-sectors, where viticulture is one of those (UC Davis Chile & CAV+S, 2019). The results of the study showed that most of the circular initiatives are related to strategies that transform discarded products or waste to give them a new function. The highlighted activities found in the study that relates to viticulture are:

- Design of lightweight bottles
- Reduction of water use in the wine production
- Use of the National Sustainability Code
- Revalorization of grape pomace for the pharmaceutical and food industry
- Compost of organic waste
- Biogas from organic waste

The study identifies CE as a valuable model for Chile and the agri-food sector with clear opportunities, such as the emergence of new business models and seizing new technologies to develop packaging.

Although there are specific studies for viticulture, these are to identify the type of circular activities that are being implemented, and not to quantify the current status or the impact of implementing these activities.

3 Theory: Circular Economy

In this section, a review of the most relevant theory and approaches related to the research topics is carried out. An analytical framework linking these is presented as a summary of the section.

The main theory used in this research is Circular Economy (CE), which is a concept that has risen as an alternative to the current linear model claiming to be more sustainable (Bocken et al., 2018; Geisendorf & Pietrulla, 2018; Ghisellini, Cialani, & Ulgiati, 2015). It is a widely discussed topic nowadays, with several different definitions and it has evolved within the years (Geisendorf & Pietrulla, 2018; Geissdoerfer et al., 2017; Kirchherr et al., 2017; Reike et al., 2018). We understand CE as a regenerative system which pursuits to slow, narrow and close the resources loops by maximizing the value retention at the different levels of the system.

In the following subsections, it is explained the relevant ideas related to CE that are needed for this research and how these connect to the packaging and/or wine industry.

3.1 Value retention options

The most common concepts used to operationalize CE is the 'R' hierarchy, which stands for the terms starting with 'Re' that means again. The number and meaning of 'R' differ between authors, ranging from '3R', where there is no consensus what is included; up to the more thorough '10Rs' (Reike et al., 2018). Due to the high inconsistencies in the 'R' terminology, Reike et al. (2018) put forward the term value retention options (ROs) to refer to the conservation of resources closest to their original state, and in the case of finished goods retaining their state or reusing them with a minimum of entropy as to be able to give them consecutive lives. Also, they conceptualize each of the '10R' (Table 3.1) in a hierarchized framework (Reike et al., 2018).

Table 3.1: '10Rs' or value retention options; own elaboration based on Reike et al. (2018)

	R#	CE concept	Description	Owner
Downcycling	R9	Re-mine	To retrieve materials after the landfilling phase	Local authorities
	R8	Recover	To capture energy embodied in waste	Collector, municipality, energy company, waste mgt. company
	R7	Recycle	To process mixed post-consumer products or post-producer waste streams	Collector, processor, waste mgt. company
	R6	Repurpose	To give a distinct new life cycle to a material	New user
Product upgrade	R5	Re-manufacture	To disassemble, check, clean and replace or repair the full structure of a multi-component product	Original or new customer
	R4	Refurbish	To replace or repair resulting in an overall 'upgrade' of the product while a large multi-component remains intact	Original or new customer
	R3	Repair	To extend the lifetime of the product	1st and 2nd consumer
Client/user choices	R2	Resell/Reuse	To bring products back into the economy after initial use	Consumer
	R1	Reduce	To eliminate the production of waste	Consumer
	R0	Refuse	To buy less or to use less	Potential consumer

There is another important distinction to make that is between the so-called biological cycle that encompasses organic and renewable materials and technical cycle that includes inorganic and synthetic materials (Bocken et al., 2016; Braungart, McDonough, & Bollinger, 2007; McDonough & Braungart, 2002). Agri-food, such as wine, is part of the biological cycle and there are two main strategies to deal with its waste to become more circular: i) composting or anaerobic digestion and ii) recover of high value (bio) chemicals (Lin et al., 2013). Wine is known to be rich in useful molecules and its secondary materials are valorised and not considered as waste. Six litres of wine produce one kilogram of grape pomace, which according to European Council Regulation must be sent to alcohol distilleries, producing alcohol and tartrates, obtaining another by-product, named exhausted grape marc. This by-product is used to extract biologically active biomolecules that are used in the nutraceutical and cosmeceutical industry (Tacchini et al., 2019). And so, research suggests that there are enough initiatives to close the loop of the biological cycle of wine (Arvanitoyannis, Ladas, & Mavromatis, 2006; Lin et al., 2013; Tacchini et al., 2019).

On the other side, the packaging used in wine has materials that are part of the biological cycle, as well as the technical cycle depending on the materials used for it. It has received much attention in terms of sustainability and is potential to use CE strategies as a solution. Despite the criticism, the packaging has great benefits in reducing product waste (Emblem, 2012). Hence, the main criticism, should not be the existence of packaging, but the linear model that has been exploited where it is seen packaging as a temporary by-product that becomes waste after a single-use. Strategies to improve circularity for packaging fail if its function is not considered along the supply chain and in combination with its product, thus it has to be considered as a product-packaging combination (de Koeijer, Wever, & Henseler, 2017).

There is a specific 4R's strategy created for the product-packaging combinations that consider the challenges of these type of goods (DelftX, 2019). It defines recycle and reuse with the same meaning of the literature, only that the scope is product-packaging combinations. Rethink means reimagining the design or application of the packaging and minimise negative environmental and societal impacts. They add a new strategy called renew that refers to the of use renewable and/or biodegradable materials in packaging, it represents the biological cycle.

3.2 Circular business models

Circular Business Models (CBMs) are a key enabler for the shift from a linear to a CE (Henry, Bauwens, Hekkert, & Kirchherr, n.d.). Moreover, CBMs are seen as a way of operationalizing CE (Bocken, Strupeit, Whalen, & Nußholz, 2019; Ghisellini et al., 2015).

Nevertheless, CBMs are not yet widespread because of the need to change the key building blocks of the business, as well as the need to challenge dominant business paradigms (Bocken et al., 2019). A business model articulates how a business creates and delivers value to customers, it also defines the architecture of revenues, costs, and profits associated that value (Teece, 2010). Richardson (2008) created an integrative business model framework that identifies value proposition, value creation & delivery system and value capture as the key elements to formulate business strategy.

CBMs are driving supply chains to transform towards circularity by closing, slowing, intensifying, narrowing and dematerializing loops (Geissdoerfer, Morioka, de Carvalho, & Evans, 2018).

3.3 Circular supply chain

The supply chain is understood as the flow of goods and services from origin to customers, it interconnects business, activities, information and processes. It exists in an exchange relationship with value chain, that refers to the flow of revenue from the end consumer of any product and service, which provides the revenue stream for each stage of the supply chain (Cox, 1999). And so, supply chains link value chains from the business.

Circular supply chains focus on maintaining biological and technical cycles of materials by optimizing the value from reverse and sideway flows which in theory provides endless cycles of materials (Weetman, 2016). On the contrary, supply chains that follow the linear model optimize the forward flow relying on accessible raw materials of which limited quantities return to the system after manufacturing and use resulting in a depletion of raw materials and a surplus of waste (de Koeijer et al., 2017).

3.4 Theoretical framework

Figure 3.1 represents the theoretical framework used for this research, it illustrates how CBMs use ROs to close the material loops to transform the traditional linear supply chain into a circular one.

The packaging supply chain has the function to provide information and to deliver safely and in good quality the wine. It interacts with the wine supply chain (white boxes with red border) at different processes depending on the type of packaging. Primary packaging which contains the wine itself (i.e. bottles) is the first used in the supply chain (pale green). Then, the secondary packaging (i.e. cardboard box) that holds together the primary packaging is used (pale brown). Finally, the tertiary packaging (i.e. pallet) is used to transport safely the wine to retailers (pale sky-blue). The packaging enters the wine supply chain as a resource and leaves it as waste; in inverse order as it was introduced. Circular business models provide the services needed to implement the ROs (pale grey) that keep the nutrients in the cycle.

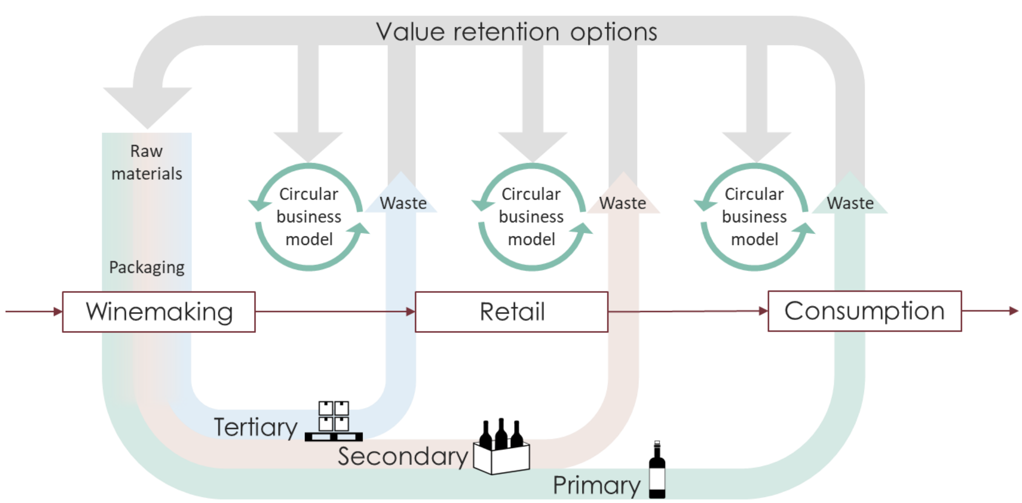

Figure 3.1: Framework linking the theories used in this research; own elaboration

In the next chapter, the methods are described based on the concepts explained in the theoretical framework.

4 Methodology

The research aimed at determining quantitatively to what extent circular business models can reduce the waste generated from packaging, by studying the case of the domestic market of the Chilean wine industry. First, the data collection was performed for the overall study. Then the operationalization stage took place, where an indicator to show the state of the waste generation due to packaging was defined. Finally, we divided the analysis of the data extracted during the first stage, into three parts that followed the rationale of the sub-research questions. It is on this stage where, we determined the current inputs, flows and outputs of the system using a Material Flow Analysis (MFA). Afterwards, we devised different configurations of the supply chain based on high-retention value options. Finally, we compared the current situation with the new configurations to quantify the degree which is possible to reduce the waste due to packaging. Table 4.1 shows a summary of the methodology.

Table 4.1: Summary of the methodology

<table>
<tr><td colspan="4">To what extent circular business models can decrease the waste generated from packaging in the Chilean wine supply chain for its domestic market?</td></tr>
<tr><td>Research design</td><td colspan="3">Case study</td></tr>
<tr><td>Research strategy</td><td colspan="3">Quantitative</td></tr>
<tr><td colspan="4">1. Data collection</td></tr>
<tr><td>Data collection</td><td colspan="3">Desk research and interviews</td></tr>
<tr><td>Data gathered</td><td colspan="3">Academic papers, case studies, governmental and associations databases, annual reports from associations, sustainability or integrated reports from companies.</td></tr>
<tr><td>Sampling</td><td colspan="3">Purposive and snowball</td></tr>
<tr><td colspan="4">2. Operationalization</td></tr>
<tr><td>Operationalization / Indicator</td><td colspan="3">Tons of waste by the materials selected that end landfilled</td></tr>
<tr><td>Scope</td><td colspan="3">The Chilean wine industry in the national territory</td></tr>
<tr><td colspan="4">3. Data analysis</td></tr>
<tr><td>Sub-questions</td><td>How is the current amount of waste generated from the packaging?</td><td>How can circular business models affect the configuration of the supply chain?</td><td>What would be the amount of waste generated considering the new circular supply chain configuration?</td></tr>
<tr><td>Data analysis</td><td>Material Flow analysis</td><td>Value retention options framework</td><td>Material Flow analysis</td></tr>
<tr><td>Outcome</td><td>Packaging and waste flow characterization for the current system</td><td>New supply chain configuration</td><td>Packaging and waste flow characterization for the new configuration</td></tr>
<tr><td colspan="4">Result: The extent that waste could be reduced using CBM</td></tr>
</table>

4.1 Data collection

To understand the current packaging supply chain and devise new configurations, numerical and non-numerical data was collected through desk research and semi-structured interviews with industry experts. First, we looked for academic papers, case studies and industry association's reports using the web search engine Google Scholar to have an overlook of the wine industry; in specific which was the state of the art in the Chilean industry. Then, we looked for aggregated numerical data in databases and reports from the Chilean government, wine and packaging associations in Chile. Afterwards, by following a purposive sampling (Bryman, 2012), we looked for sustainability or integrated reports from companies in the wine supply chain. Also, we contacted executives in these companies for data triangulation; we asked for more detailed information to complement and corroborate the information found in the company's reports. Then we followed a snowball sampling (Bryman, 2012), asking for more contacts to talk. In the first contact with the high executives, we explained the aim of the study, relevance and how they could help us. Then we asked for a semi-structured interview and/or specific numerical and non-numerical data related to the organization. We were flexible in the way we approached our interviewees because we knew that we had strong barriers such as geographical distance, time difference and high executives usually have limited time. Therefore, we approached different contacts within the companies, and we accept different types of answers, audio, written or video-call.

Semi-structured interviews were performed to understand the packaging, supply chain and the circular initiatives present. We use the live coding procedure of Parameswaran, Ozawa-Kirk, & Latendresse (2019), characterized by recording the interviews and coded directly from the records without transcribing it. The main benefit of this procedure is that allows to code non-verbal behaviour (e.g. nodding). On the other hand, the main disadvantages relate to cultural nuances to read the non-verbal behaviour and difficulty to search for words or concepts. This disadvantage was reduced by having an interviewer from the same country that understands the cultural nuances. The procedure for the interviews started with the elaboration of the semi-structured interview guide (Annexe 10.1), which is recursive in nature. We calibrated it accordingly to the interviewee's company role and included additional questions as they arose in subsequent interviews. The interview itself was performed where a conference/call software allows audio and video recording. It is important to note that many of the interviewees were geographically distant to the interviewer, therefore was convenient to have an audio and video conference/call instead of face to face interviews. After this, the audio and video were watched and listened to take notes and code. Specific quotes were transcribed and additional revisions to the recordings were made. The interviews were made until saturation of data (Bryman, 2012).

Concerning reports and figures, we searched for the most recent data available because the last year of data could vary from one source to another. Also, we looked for a year series to check for the stability of the data and decrease the possibility that we chose a year that has abnormal behaviour. Data from different sources were triangulated to compare it and check the validity.

The data collected was used to perform an MFA for the current new configuration, as well as to devise the new configuration.

4.2 Operationalization

We aim at measuring the decrease in waste production due to CBM; thus, we chose as an indicator, the amount of material for a selected good that end landfilled (in tons).

The scope and population ('limited intended domain') of this study was the domestic market of the Chilean wine industry. The sample ('achieved domain') was the companies with the largest share in the wine market because they are the ones that have more influence in the total volume of waste packaging production (See Section 2.1.2).

The unit of analysis for this research was the primary, secondary and tertiary packaging for wine. For each type, we selected the most common packaging used and the predominant material in weight, as shown in Table 4.2.

Table 4.2: Description of the unit of analysis

Packaging type	Label	Material	Description
Primary	Bottle	Glass	Glass bottle of capacity 750 ml with a weight that varies from 360 g to 1065 gr. The colour varies from transparent to different shadows of green and brown.
Secondary	Box	Corrugated cardboard	Corrugated cardboard box with a capacity of 6 or 12 bottles with dividers.
Tertiary	Wood Pallet	Wood	Pallet made of wood with an area of 100 x 120 cm and a weight of 25 kg.
	Plastic Pallet	Polypropylene	Pallet made of polypropylene with an area 100 x 120 cm and a weight of 22 kg.

4.3 Data analysis

4.3.1 Current system: Material Flow Analysis

We chose to analyse the data using an MFA because it allows quantifying flows and stocks using mass balance when the system is well-defined. The procedure was based on Brunner & Rechberger (2005) which establishes different steps to be followed in an iterative process. This procedure suggests starting with rough estimations and then iterate to refine the calculations until the required quality and certainty is achieved. Figure 4.1 shows the different steps used in this research and the sequence followed. The first step of this procedure is the problem definition. The second step was to define the system by determining system boundaries, processes, and goods; in other words, the supply chain was determined and with that. The third step was to calculate mass flows and stocks. The fourth and last step was to present the results in an appropriate visual way.

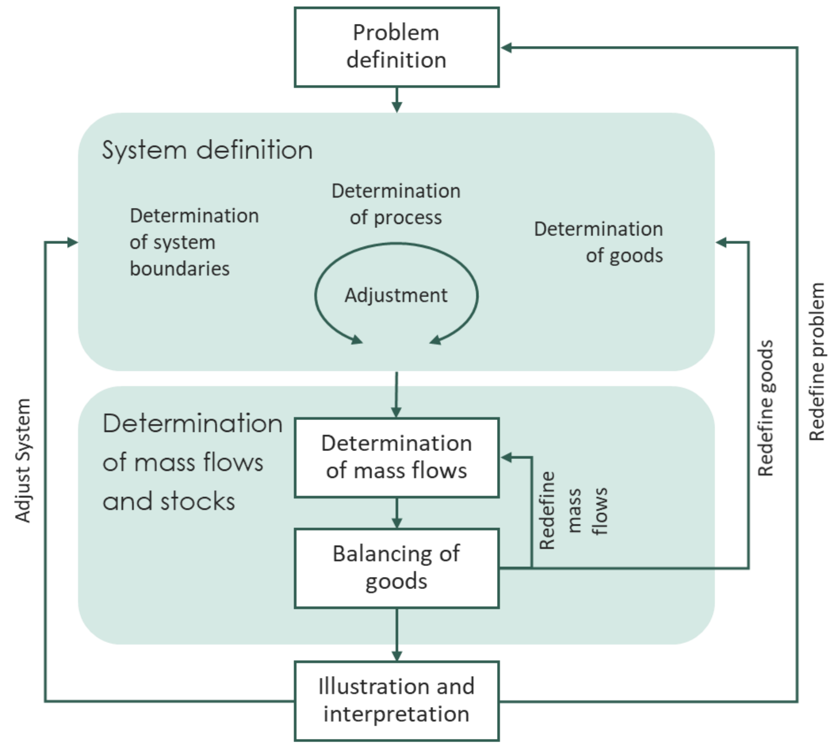

Figure 4.1: Procedures for MFA; own elaboration based on Brunner & Rechberger (2005)

MFA Step 1: Problem definition

To define the problem, we did an exhaustive literature review. We looked for the current research and state of the art in the packaging for the domestic market in the Chilean wine industry and found that the knowledge gap is the amount of waste produced due to wine packaging and at what extent circular initiatives could reduce it (See Section 1.1).

MFA Step 2: System definition

The system definition corresponds to the selection of appropriate system boundaries, goods and processes. The system boundaries were defined in time and space. The temporal system was defined as one year. The spatial system boundary was determined by the scope of the study (Section 4.2). To select the relevant goods, we chose the most common package used for each type, primary, secondary and tertiary. Then we chose the predominant material in weight for each type of package. To select the processes, first, we mapped the value chains for wineries and packaging manufactures of the selected goods. Then, we simplified the chain to only the processes that change the flow of the selected good by merging processes. After that, all the value chains were put together to define the system.

According to Brunner & Rechberger (2005), the definition of the system is a decisive task and has a direct influence on the quality of the results of an MFA. Thus, this followed an iterative process and was constantly reviewed as new calculations and insights appear.

MFA Step 3: Determination of mass flows and stocks

The mass flows were initially calculated for each good separately, to obtain a rough estimation. Then, the calculations for the goods were combined into one model allowing to calculate the flows more precisely and integrated. We started our calculations with material flows that are commonly reported, such as, glass production. Then we calculated the value of the flows downstream and upstream from the supply chain. With other commonly reported materials flow, we checked that our estimations were correct both downstream and upstream. To estimate the initial material flow, we studied several years of production and different data sources to triangulate information and find the most precise value with the data available.

MFA Step 4: Illustration and interpretation

We used a Sankey diagram to present the results.

The results of the four previous steps described are shown in Section 5.2. It is important to mark that the quality of an MFA depends directly on the use of reliable and consistent data (National Research Council (U.S.) & National Academy of Sciences (U.S.), 2004). See Section 4.1 for the quality of data.

4.3.2 Circular supply chain configuration devising

To identify and define the circular Supply chain configuration, first, we identify existing circular initiatives in the current wine supply chain using the value retention options (ROs) defined by Reike et al. (2018). The second step is to look for best practices with higher value retention options used in other similar industries and international practices (i.e. other beverages), we ascertain, with experts' opinions, if the practice found can be applied to the Chilean wine industry and adjust if necessary. The last step is to devise the new supply chain configuration by determining the processes and goods (Results in Section 5.2).

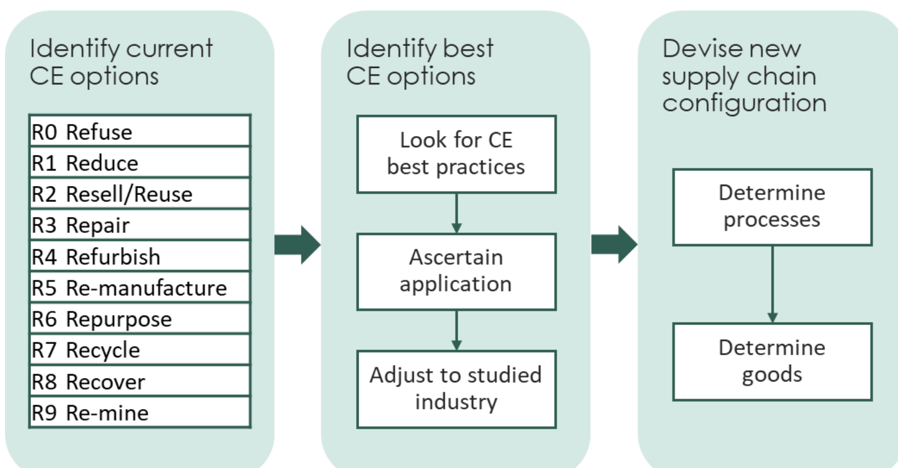

Figure 4.2: Steps to devise new circular supply chain

4.3.3 New configurations: Material Flow Analysis

The procedure from part 1 was replicated using the configuration of the circular supply chain obtained in part 2. The result was the waste produced considering a new circular supply chain configuration (Results in Section 5.3). A comparison was carried between both materials flows, to understand the extent to which circular business models can decrease the waste generation for packaging in the Chilean wine industry (Results in Section 5.3).

All assumptions and calculations made during the data analysis are provided in Annexe 10.2 to ensure transparency in the procedure.

5 Results

In Section 5.1 the current waste generation is quantified for the domestic market in the Chilean wine industry. A new configuration for the supply chain is devised using CBM (Section 5.2) and its flows are calculated (Section 5.3). Section 5.4 illustrates the results of both systems.

5.1 Material Flow Analysis for the Chilean wine industry

We found aggregated numerical data related to wine production in Office of Agricultural Studies and Policies (ODEPA, 2020) and wine consumption in Wines of Chile (Vinos de Chile, 2013, 2017). Sustainability reports of packaging manufacture companies; glassmaking companies (CristalChile, 2016; Cristoro, 2018; Verallia, 2019), paper manufacture (Arcor group, 2018; CMPC, 2018; International Paper, 2018; Smurfit Kappa, 2018), wood and plastic pallet there were no public reports available. Also, we performed six interviews with industry experts, where we obtained data related to the current supply chain configuration.

Our problem definition is to evaluate quantitatively the amount of waste generated due to wine packaging in Chile. The spatial boundaries to solve this problem were defined in the national wine industry and the temporal ones were set for one-year production in 2017. The selected goods were: i) 750 ml glass bottles for primary, ii) corrugated cardboard box for secondary, and for tertiary packaging iii) wood pallets and iv) plastic pallets. The system was too complex to be analysed, therefore we first studied the supply chain for each good and then we combined them in an integrated system.

We did not include energy and emissions because our interest lied in material waste although we acknowledge these are relevant aspects for the sustainability of the wine industry.

5.1.1 Glass bottles current system

Verghese, Fitzpatrick, & Lewis (2012) describes the general process of bottle manufacturing. Glass is originally manufactured from natural raw materials, such as silica sand, calcium carbonate (limestone), soda ash and cullet (recycled glass). Silica sand and calcium carbonate allow the different types of packaging to be shaped. Soda ash has the role of lowering the melting temperature. To prepare cullet, first, the contaminants and labels present are removed. Removal of labels occurs by immersing the bottles in a caustic soda bath which increase economic and environmental costs. These materials are mixed and melted at 1.500º C. Shaping of wine bottles usually occurs by the blow and blow process. After this process, bottles are completely formed and are transferred to the annealing lehr. Where they are reheated and allowed to cool down at an even rate to eliminate internal stresses that could lead to cracking or shattering (Figure 5.1).

Before distribution, bottles are subjected to careful inspections to ensure they meet quality control guidelines, 10% to 15% of the wine bottles present defects and are melted again (High executive at glassmaking, personal communication, February 11, 2020). Then, they are washed and packed. Bottles are packed using a pallet, separators and a plastic wrap accommodating between 910 and 1960 bottles disposed of in 5 to 7 layers with a total weight that vary between half and one tonne.

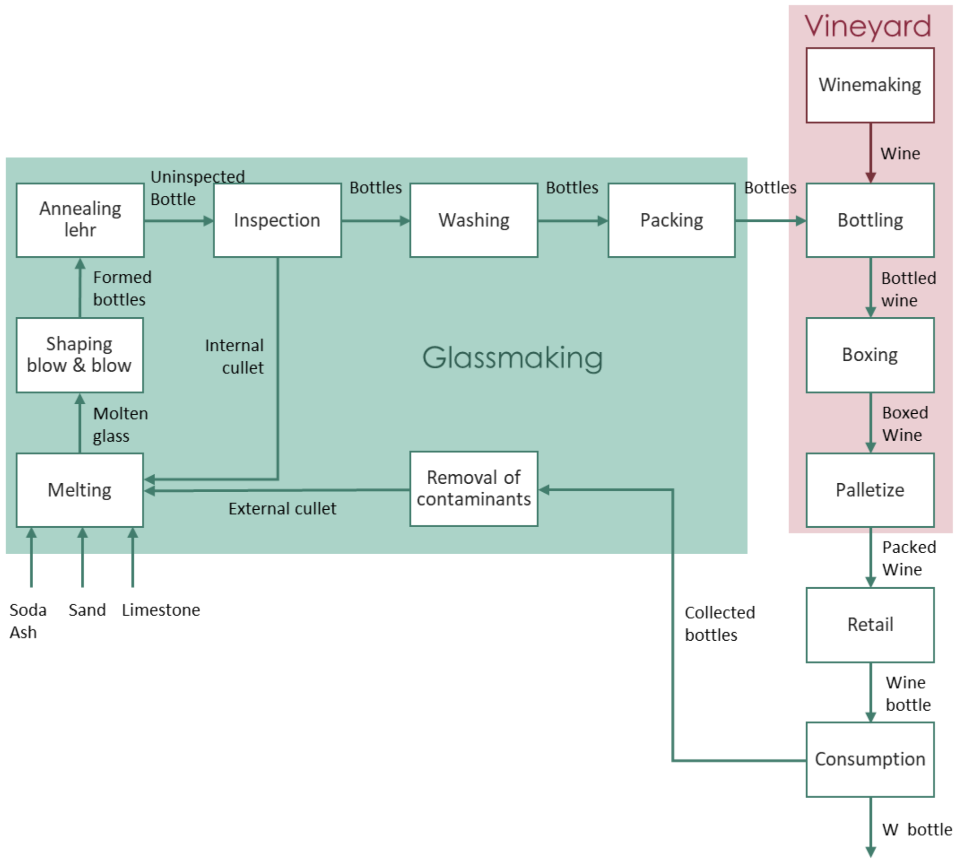

Figure 5.1: Glass bottle current system

5.1.2 Cardboard box current system

A corrugated cardboard box needs mainly two raw materials to be manufactured: paper and adhesive. Paper's primary raw material is trees which are part of the biological cycle. Certifications such as FSC and PEFC give guidelines to manage the forest sustainably. CMPC, the largest paper manufacturer in Chile, has a zero-waste plan which consists of recover energy from the effluent sludge, and then use the ash to improve the forest soil (CMPC, 2018).

As far as we are concerned, there is no public information available considering the type of adhesive used by the companies. 'Envases Impresos' mentions in their website that uses native corn starch mixed with chemical components (Envases Impresos Roble Alto, n.d.). It seems that the strategy of the companies is to use a type of glue that allows the after-lifetime recycling process. Although it is important to know the circularity of adhesives, given the difficulty to acquire data we focused our attention to the process of paper-cardboard rather than the glue.

The process to manufacture a corrugated cardboard box starts with the manufacture of the corrugated cardboard plank which is fundamentally made up of a flute sandwiched between two liners (Dekker, 2013). The manufacturing process is made by a machine that folds the flute and glues it to the liners in the desired shape. Then, the plank is shaped in a die-cutting process where the cut-off pieces are collected and recycled. Then, the cut pieces are packed unfolded to be transported to the vineyards or bottling facilities. The final shape is given in the bottling line, wrapping around the filled wine bottles (Figure 5.2).

It was not possible to calculate the material flows for this system because it was not possible to gather enough specific data. We did not receive any answer from the contacted companies and the available information from reports was not enough data to calculate the material flows.

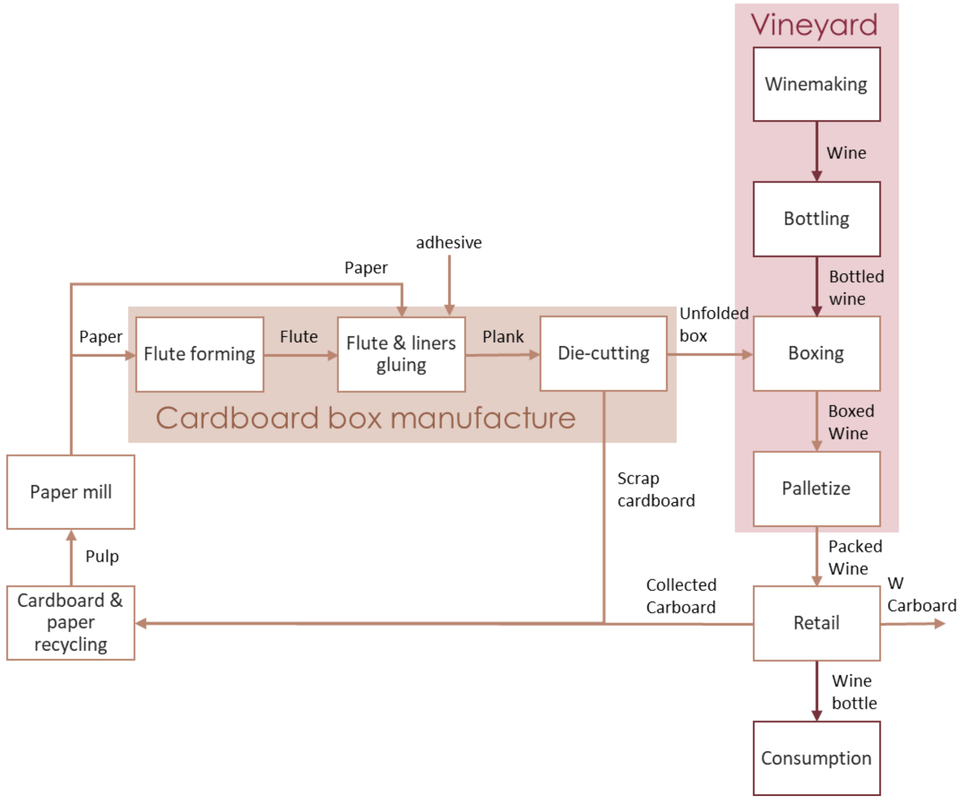

Figure 5.2: Cardboard box current system

5.1.3 Wood pallet current system

Pallets are classified into three general groups: Expendable or nonreturnable, general-purpose or reusable, and special purpose (Forest Products Laboratory & Forest Service U.S. Department of Agriculture, 1971). this study focuses on the general-purpose or reusable pallets as our system boundaries are set for the national market and usually the geographic distance allows the pallet to be returned.

Pallets are generally simple in design, and fabrication commonly uses two materials: lumber and steel nails. The lumber used is lower grades of either hardwood or softwood depending on the requirements. For the Chilean case, we could not find any evidence that sustainably managed wood was used; both clients and manufactures ignore the existence of this kind of certifications. Steel nails are used as fastenings for the lumber's pieces which needs to be properly nailed to develop the maximum strength. Many quality problems can be traced to the wrong nailing (Forest Products Laboratory & Forest Service U.S. Department of Agriculture, 1971).

Pallets plants layout varies from artisan to fully automated work. Thus, the detail of the processes involved in the manufacturing of them varies much, but there are some characteristics that all processes share.

The machinery and conveyors used is arranged to provide a direct flow from receipt of the raw materials to the shipment of finished pallets. In some cases, the raw pallet lumber must be ripped to width, cut to length, surface planed, and possibly resewn to thickness before being assembled or it could be procured already finished (Forest Products Laboratory & Forest Service U.S. Department of Agriculture, 1971). Then, the pieces of wood are placed in the desired position and they are nailed together. After this, the pallets are transported into the drying room, where the pallets are dried to the customer's specified moisture level (Kočí, 2019). Some pallets also receive a thermal or chemical treatment to comply with ISPM 15 being mandatory for exports and imports, but not for domestic use (Servicio Agricola y Ganadero, n.d.).

After the pallets are finished, they are transported to the bottling facilities where are loaded with boxed wine and then transported to the retailers (Figure 5.3).

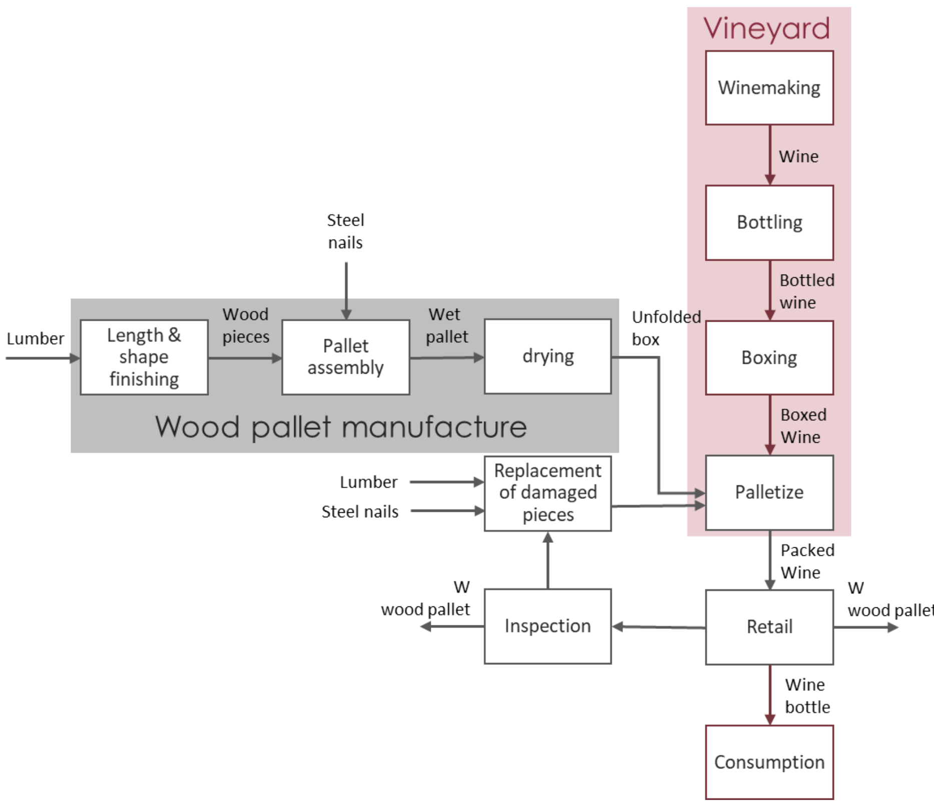

Figure 5.3: Wood pallet current system

5.1.4 Plastic pallet current system

There are several different types of plastic pallets and manufacturing processes. The raw material most commonly used in the Chilean wine industry is virgin and recycled polypropylene (High executive at a plastic manufacturer company, personal communication, March 26, 2020). Colourants are also used in a smaller proportion by volume; thus, we are going to focus on polypropylene process.

The usual manufacturing process is injection moulding, where raw materials are heated and melted in a barrel with a rotating screw, then there are injected into a mould. Finally, is applied pressure to fill the mould with the melted materials and ensure the desired shape. (Hassanzadeh Amin, Wu, & Karaphillis, 2018) (Figure 5.4).

The business model of the plastic pallet manufacturing company incentivizes the return of damaged pallets. Therefore, we consider that all the pallets return to the company and no waste is produced.

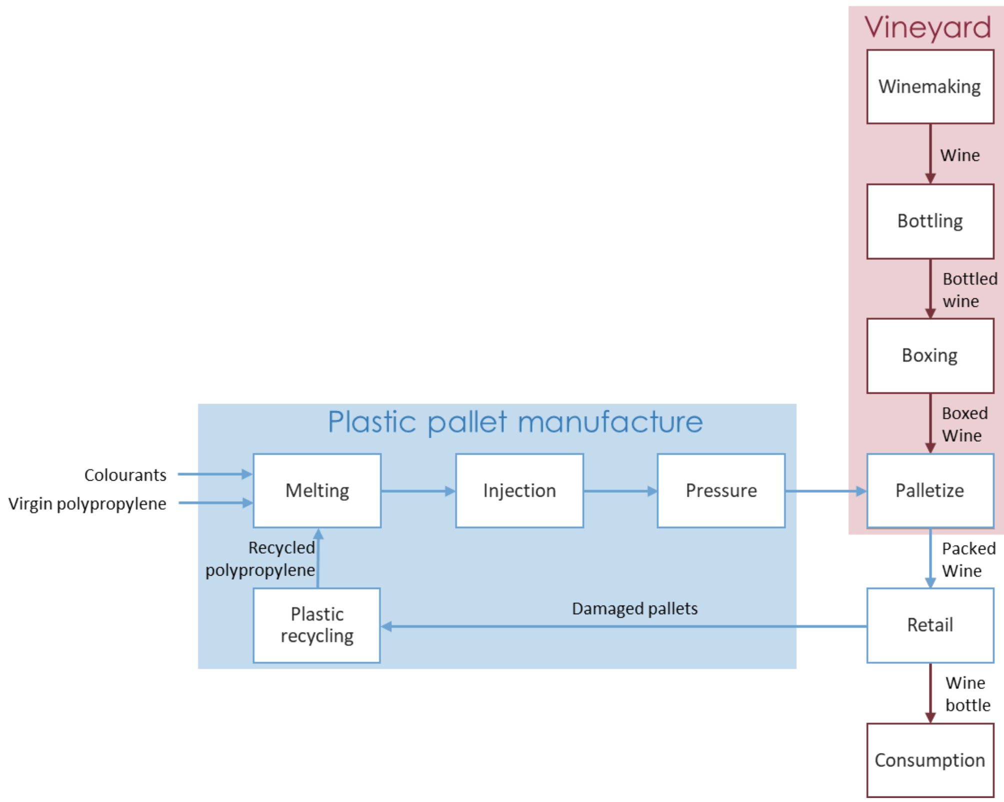

Figure 5.4: Plastic pallet current system

5.1.5 The current wine packaging system

Figure 5.5 illustrates the wine packaging system, including primary (e.g. glass bottle), secondary (e.g. cardboard box) and tertiary packaging (e.g. wood and plastic pallet). Each type of packaging flow is shown in another colour. The system boundaries are shown with a dashed line. Bottling, boxing and palletize are the processes that introduce the primary, secondary and tertiary packaging into the system. Retail is the process that discards the tertiary and secondary packaging. Consumption is the process that discards the primary packaging of the system.

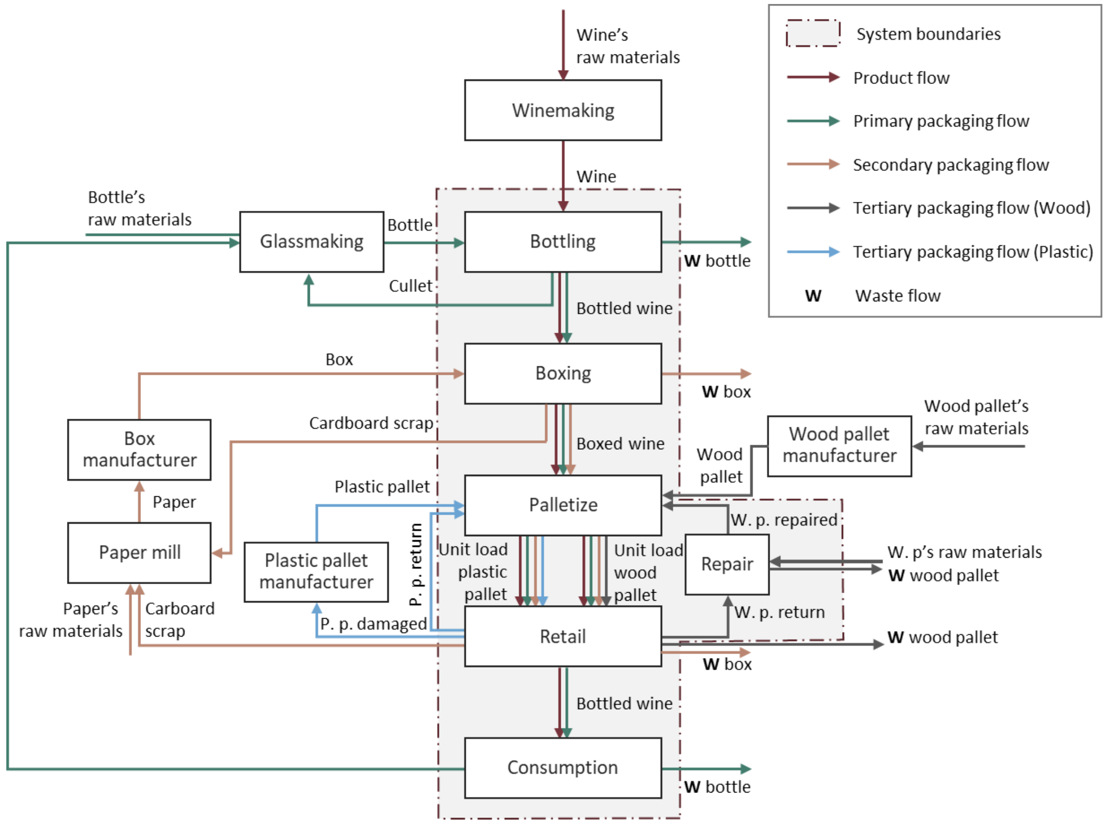

Figure 5.5: Current system for primary, secondary and tertiary packaging

The initial value to calculate the packaging flows is the national sale of 189 million litres for wine packed in 750 ml glass bottles for the year 2017. Figure 5.6 shows the total national wine sales per year including all type of packaging. It decreases from 229,1 to 218,3 million litres in the period 2008 – 2013 (Wines of Chile, 2019). Wines of Chile introduced that year their strategy for 2020, which has an objective to increase the consumption and the unitary price by improving wine reputation (Vinos de Chile, 2013). Consequently, sales increased up to 261,4 million litres for 2017. The historic quantitative evolution of formats was available only for 2016 and 2017, where bottled sales represented 68,9% and 71,3% from the total respectively (Vinos de Chile, 2017).

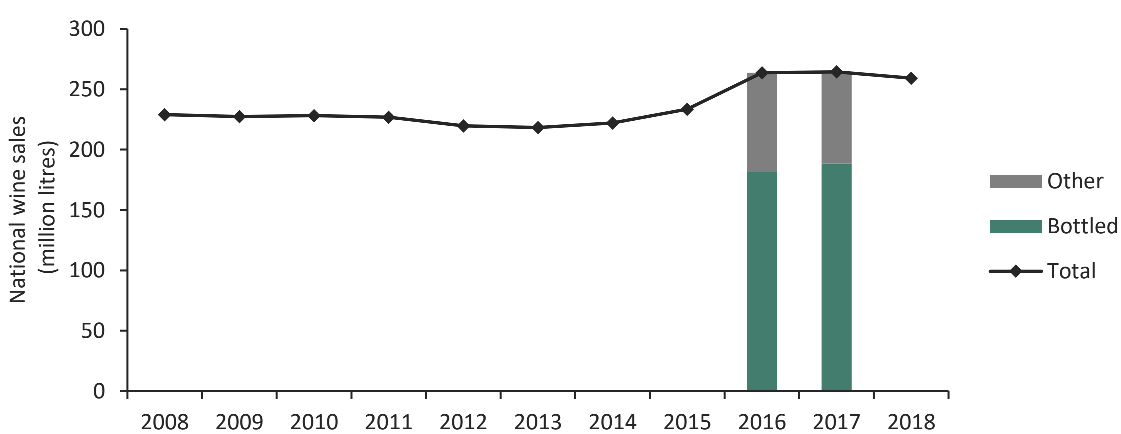

Figure 5.6: National sales per packaging type; own elaboration based on Vinos de Chile (2017) and Wines of Chile (2019)

Table 5.1 shows the waste landfilled for each type of packaging in units and weight. The details of the calculations are indicated in Annexe 10.2.1.

Table 5.1: Total waste that is landfilled for the current system

Waste flow	# units	Weight (ton)
Glass bottle	170.947.651	70.089
Cardboard box	9.237.554	3.695
Wood pallet	633.041	15.826
Plastic pallet	0	0
Total		**89.610**

Glass bottles generate the largest waste stream with more than 170 million units and 70.089 ton per year. It is followed by 9 million cardboard boxes units representing 3.695 ton per year. Wood pallets waste 633 thousand units which translates to 15.826 ton. Although, cardboard boxes waste represents more units than wood pallets, in weight it is the opposite, as a one-unit pallet is way heavier than a cardboard box. As discussed in Section 5.1.4, plastic pallets do not generate waste that ends in a landfill, because its business model ensures that its clients return the damaged pallets to be recycled.

Inspired in the concept of energy intensity which measures the inefficiency of transforming energy into economic terms, we defined 'Packaging intensity'. It represents the amount of packaging that is wasted per wine consumption. It is calculated as the weight of packaging waste per volume of wine consumed, it is calculated in [g/L] as shown in formula (1). For this calculation, waste refers to all the packaging material that leaves the system ending in a landfill.

$$Packaging\ intensity = \frac{Packaging\ waste}{Wine\ consumption} \quad \left[\frac{g}{L}\right] \qquad (1)$$

Figure 5.7 illustrates the packaging intensity for the current system. The glass bottle is shown in green, the cardboard box in brown colour, wood pallet in grey and plastic pallet in sky-blue.

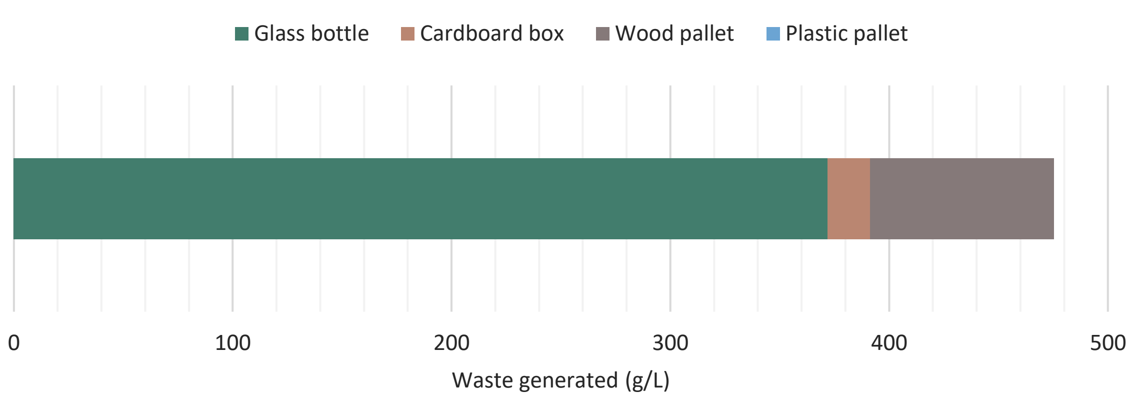

Figure 5.7: Packaging intensity for the current system

The total packaging intensity is 475 g/L, where the largest packaging intensity comes from glass bottles representing 372 g/L. The cardboard box intensity is 19,6 g/L and wood pallet intensity is 84,0 g/L. Plastic pallet contribution is cero as all the pallets return to the manufacturer to be recycled.

5.2 Devise of the circular supply chain configuration

5.2.1 Identification of the current value retention options

From the desk research and interviews, we identified the ROs present in the Chilean wine supply chain according to Reike et al. (2018). We describe them from the least preferred longest loop 'R9' to the shortest most preferred loop 'R0'.

5.2.1.1 Long Loops

Long loops are the ones that are related to closing the loop and traditionally considered as waste management activities. These are the least preferred options to reach a circular economy.

The waste of wine packaging is considered as a non-dangerous waste originated from domiciliary and industrial waste streams. Most of the volume of primary and secondary packaging is generated by end consumers and retailers. Tertiary packaging is produced by industries or transport companies. Most of the non-dangerous waste in Chile ends in landfills representing a 76,4% with just a 23,6% being valorised (Ministerio del Medio Ambiente, 2019). Valorisation of waste has occurred with free-market forces being the price of the material the main driver. In the last years, the government has promoted incentives such as EPR law and subsidies to increase waste valorisation. According to CyV Medioambiente (2010) study, the main barrier to the valorisation is in the chain 'generation-collection-transport-sorting'. Therefore, it is likely that we can conclude that wine packaging waste is not sorted, and it is found mixed with other sources.

R9 Re-mine: Understood as retrieval of materials after the landfilling phase. For Chile, there is no specific legislation concerning the concept of re-mine. The current legislation DS 189/2005 for landfills establishes the sanitary and security guidelines and does not mention the possibility to re-mining materials from them neither. It also states that retrieval of materials needs to be done in a conveyor belt on a properly closed infrastructure, which makes the option for re-mine unfeasible. It is possible, that some illegal re-mine is occurring as only the 78,2% of the waste ends in a legalized landfill (SIGA, 2018; SUBDERE, 2019). This activity should diminish due to the efforts made by the Chilean government to eliminate illegal disposal. In conclusion, it is not possible to determine if re-mine is currently used for wine packaging, in case this is taking place, it is reduced and expected to diminish.

R8 Recover: Understood as capturing energy embodied in waste, linking it to incineration in combination with producing energy or the use of biomass (i.e. wood pallets). Currently, there are no waste-to-energy incineration plants in Chile. Some feasibility studies have been done, but the gate fee for landfills are low making a project of this type not economically viable (Themelis, Elena, Barriga, Estevez, & Velasco, 2013). In specific for waste packaging, recover is not included as a strategy to achieve the preliminary goals for valorisation in Resolución 544 Exenta/2019. Therefore, recover is not expected to be used as a strategy in the Chilean waste management system for packaging in the wine industry.

R7 Recycle: Although the overall recycling rate for the year 2017 was 11,8% (Ministerio del Medio Ambiente, 2019), there are big differences between industrial and domiciliary waste, and between different waste streams. CyV Medioambiente (2010) reported that for the year 2009 the recycling rates were: glass 53%, cardboard and paper 81%, wood 55% and plastic 12%. The National Association of the Recycling Industry informed that in 2017 32% of the glass and 78% of the cardboard and paper were recycled (ANIR, 2018). It is difficult to ascertain the recycling rates for a specific product, as it is almost impossible to identify the origin of each material as it gets mixed at its disposal and no records are kept.

5.2.1.2 Medium Loops

In medium loops, products are upgraded, and producers are involved in this cycle.

R6 Repurpose: Focussed on adapting a product's waste or by-product for another function, this strategy gives the material a distinct new life cycle. This can be observed when entrepreneurs use a durable material found in waste and create a new product with a higher value. For glass bottles, we found small businesses that fabricate glasses and candles from cutting disposed bottles; it is possible to identify that some of their new products come from used wine bottles (Green Glass, n.d.; Vivo en Pass, n.d.). Similarly, some companies use wood pallets to manufacture furniture, compost bins and promotional stands for fairs (Don Pallets, n.d.; Pantano Pallet, n.d.). Some of the products use the entire pallet, but others disassemble it completely, to use the raw material, making it impossible to recognize that the new product comes from an old pallet. Arguably, this example could be considered as a recycling option but since the wood is used as it is, and not processed to obtain raw material, we define this activity as an R6 example. Eh! Pale manufactures lamps from used cardboard as a business extension from their pallets furniture (Eh! Pale, n.d.). Plastic pallets do not have R6 activities because they usually return to their suppliers. One of our interviewees explained that their business model includes an incentive to return pallets; where they give one pallet free for every five pallets returned.

R5 Re-manufacture: This option is used when the full structure of a multi-component[2] product is disassembled, checked, cleaned and replaced or repaired in an industrial process. This strategy doesn´t apply to glass bottles, cardboard box, wood pallet and plastic pallet, as our goods studied are not multi-component.

R4 Refurbish: This option refers to when the overall structure of a large multi-component product remains intact, while many components are replaced or repaired, resulting in an overall 'upgrade' of the product. This option also does not apply to our goods studied as they are not multi-component.

5.2.1.3 Short Loops

Short loops are characterized by being close to the consumer and where actors on the chain aim at extending the life span of the product. In other words, the product remains close to its user and function. These loops are related to narrowing and slowing the loop.

[2] Consist of multiple different components all having (one or more) individual sets of sustainability characteristics (ISCC, 2019).

R3 Repair: this option extends the lifetime of the product. The difference between re-manufacture and repair is that this option can be done by a different actor than the producer. Packaging has a short use-phase, therefore normally its lifetime exceeds its use-phase, thus repairing is mostly unexistent. However, extending the lifetime of packaging is feasible when this is reused (its use-phase is longer) and is easy to repair. This is the case for wood pallets, which are possible to repair if the damage is very limited, thus extending its lifetime.

R2 Resell/Reuse: This strategy aims at bringing products back into the economy after initial use. We did not identify activities related to resell or reuse for wine glass bottles and cardboard boxes. The wood pallets and plastic pallets are commonly reused. The wood pallet could be reused for 10 to 15 cycles depending on the care and plastic pallets could be reused up to 1000 times (High executive at a plastic manufacturer company, personal communication, March 26, 2020). We did not find resell activities.

R1 Reduce: We understand this option as using less material per unit of production. This strategy has been particularly important for glass bottles, as new technologies and new consumers preferences allow to have lightweight bottles. The leading wineries claim a reduction of 5% to 12% in the weight of their bottles (Viña Concha y Toro, 2018; VSPT Wine Group, 2018). For the other goods studied, there were no initiatives found related to eco-design or lightweight.

R0 Refuse: We understand this option as production processes that avoid waste or refuse any virgin material. It is difficult to observe this option because production processes are usually secret.

It is important to note, that there is an instrument called Clean Production Agreement (CPA) that seeks to prevent and minimize the generation of waste and emissions from the beginning of the productive process in different industries. This is a voluntary agreement that is negotiated and signed by an industrial organization on behalf of the companies that operate in that sector and government representatives. In 2003, CCV (Chilean Wine Corporation) signed a CPA in representation for wine grape producers, wineries and vineyards with the motivation of positioning the Chilean wine as sustainable in the international market (Corporación Chilena del Vino, 2007). The agreement does not establish a specific commitment to reduce the packaging used to pack the wine itself. However, this topic is covered by CENEM (Centre of Containers and Packaging of Chile) that in 2015 signed a CPA which includes actions related with waste valorisation and eco-design, but it does not explicitly mention reducing the generation of waste or refusing the use of virgin material (CENEM, 2015).

Table 5.2 shows a summary of the ROs options found for the Chilean wine industry for each good studied. A red cross means that the RO option was not found, and a green check means that the RO was found. For glass bottles, we found three ROs one on each loop size. For Cardboard box, it was found just one RO in the long loops. Wood pallet is the material with more ROs, one in the long loops, one in the medium loops and two in the short loops. Plastics pallet has two ROs, in the long and short loops.

Table 5.2: Summary of the ROs options found in the Chilean wine industry

Loop size	R#	CE concept	Glass bottles	Cardboard box	Wood pallet	Plastic pallet
Long	R9	Re-mine	✗	✗	✗	✗
	R8	Recover	✗	✗	✗	✗
	R7	Recycle	✓	✓	✓	✓
Medium	R6	Repurpose	✓	✗	✓	✗
	R5	Re-manufacture	✗	✗	✗	✗
	R4	Refurbish	✗	✗	✗	✗
Short	R3	Repair	✗	✗	✓	✗
	R2	Reuse	✗	✗	✓	✓
	R1	Reduce	✓	✗	✗	✗
	R0	Refuse	✗	✗	✗	✗

Recycling is a well-established activity in Chile related to waste management and controlled mainly by market forces, although it exists for every waste stream, the extend of it fluctuates depending on if it is economically feasible. It is usual to find that manufactures companies have integrated recycling into their business activities to obtain low-priced raw materials and increase their environmentally friendly image (CMPC, 2018; CristalChile, 2016; Cristoro, 2018).

It is expected that the introduction of the EPR law would incentivize the development of new RO activities and especially boost recycling.

5.2.2 Identification of best practices in similar industries

Based on Section 5.2.1, we looked for RO's best practices in other beverages industries. We studied the beer and soft drinks industries as they share some of the technical aspects that wine packaging needs to fulfil. We looked to either increase the current RO or to incorporate inexistent higher value RO in the new configuration. Therefore, we focused on Recycle, Repurpose, Resell/Reuse, Reduce and Refuse.

5.2.2.1 Glass bottles best practices

Even though glass has the potential to be 100% recycled, as it keeps their properties in each cycle, the recycling rate is just 53% for this waste stream in Chile. This is explained due to low collection rates and poor sorting of municipality waste. Deposit-refund systems are an effective way to increase collection rates and with that recycling rates. This instrument is being discussed as a solution and to be implemented as part of the EPR system. Dictuc Greenlab (2019) studied different scenarios for the Chilean system based on other countries experiences and found that the highest possible collection rate is 85% when a price incentive of 0,15 USD[3] is given.

In emergent wine markets like Chile, the consumer relates the weight of the bottle with wine quality. This is expected to change as consumers get more educated in the market, which has happened with more traditional markets (High executive at a small vineyard, personal communication, April 23, 2020). Currently, the lighter glass bottle available weights 380 g representing 30% less than the average weight bottle (Point, Tyedmers, & Naugler, 2012).

[3] Incentive defined in local currency 100 CLP (680 CLP/USD) (Dictuc Greenlab, 2019)

Nowadays, it is common practice in Chile to reuse glass and PET bottles of beers and soft drinks (CCU, 2018; Cristalchile, 2019; Diario Financiero, 2019). Consumers choose this option for economic reasons, as it is cheaper than disposable, therefore as purchasing power increases the willingness to buy refillable decreases (Ceruti, 2018). Consumers recognize refillable as a more environmentally friendly alternative, and even though they express a preference for it, they often end buying the disposable option (High executive at a beverage company, personal communication, May 1, 2020). Refillable options work when there is a uniform bottle as it simplifies the reverse logistics (Patrick Albrecht, Brodersen, Horst, & Scherf, 2011), this is not the case for wine bottles, as every brand uses a different bottle to differentiate himself from their competitors. To work this out a system change is needed, and coordination of the different vineyards to agree on a standard that can be used by multiple companies. An example is made by the Beverage Recycling Cooperative, an industry steward, who implemented a container deposit program that provides services of returnable containers and established a standardized refillable bottle for breweries (Staub, 2018). In Chile, Coca-Cola incorporated a single refillable bottle for all its products to simplify their internal logistics related to sorting and to offer temporary products in returnable format (Diario Financiero, 2019).

5.2.2.2 Cardboard box best practices

Cardboard box is a biological nutrient, therefore it cannot stay in a close-loop as in the technical cycle (McDonough & Braungart, 2002). This means that some raw material needs to be cultivated and then at its end of life could return their nutrients to the earth.

There are companies such as, Nispen and 'Smurfit Kappa' that has the cradle-to-cradle certification for their corrugated packaging products meaning that they reuse their raw materials without losing value. Unfortunately, the strategies used are not publicly available, but from Smurfit Kappa, sustainability report is possible to infer that its strategies are Recover, Recycle and Reduce. Despite they declare that circular economy is at their core business, they are still sending 58% of their waste to landfills which is due to the huge amount of impurities that come with the recycled paper (Smurfit Kappa, 2018). Comparing this number with the Chilean case, CMPC group landfilled 0,4% of their waste in their paper manufacturing division and 23% in their packaging manufacture division ('Envases Impresos') (CMPC, 2018). One possible explanation is that CMPC group has the collection and recycling operations as part of their business activities, ergo it is easier to control the quality and cleanness of the recycled paper.

The cardboard box in the wine industry is used as secondary packaging, therefore most of it is discarded by retailers making it easy to collect compared with primary packaging that is discarded by consumers. The current recycling rate 78% for cardboard and paper (ANIR, 2018) is higher than the goal proposed of 70% in the preliminary EPR law for packaging (Resolución 544 Exenta, 2019). The technical capacity for recycling in Chile is estimated to be 89%, thus with better collection rates recycling could be increased (ANIR, 2018).

Refurbish is already present in the Chilean market, but the extent is limited to small products. This RO could be increased by designing bigger products, such as furniture (Hartono, 2019). We could not find market studies to estimate the amount of material that could be used, for that reason we did not include this RO.

The RO with the highest retention value, Refuse, could be implemented by sending the pallets of wine bottles without cardboard boxes, as glassmaking companies do to the wineries. This is an unknown practice in the industry raising some interrogatives that should be responded with further studies. In the case that a bottle breaks, it will mess up all the pallet (High executive at a beverage company, personal communication, May 1, 2020). The difficulty is to unpack the pallet by retailers, as automatic machines unpack the pallets at wineries (High executive at a small vineyard, personal communication, April 23, 2020).

5.2.2.3 Pallet best practices

Wood and plastic pallets share similar characteristics and consequently best practices.

Large wineries have return logistics with their biggest clients, but small wineries usually use the pallet in a disposable way. Woods pallet usually can be returned 10 times while plastic pallets can be returned 1000 times (High executive at a plastic manufacturer company, personal communication, March 26, 2020).

The business model of the Chilean plastics pallets' manufacturer studied includes an economic incentive to ensure the return of them to be recycled. Despite polypropylene is not eternally recyclable as it suffers from chain scission in each cycle, in our time framework of study the waste generation is virtually zero. Thus, the current model for our boundaries of study could be considered circular.

5.2.3 Devise of the circular configuration

From the identified best practices in Section 5.2.2, we proposed a circular configuration for the packaging system of the Chilean wine industry. This configuration is based on industries' best practices and high-value RO. It was validated with experts in the Chilean wine industry.

Figure 5.8 illustrates the new circular configuration for primary, secondary and tertiary packaging for the Chilean wine industry. The same processes of the current system (Figure 5.5) are maintained, the difference is the size of the output flows and the incorporation two circular business models: Deposit-refund services for glass bottles and Transport & logistics services for pallets.

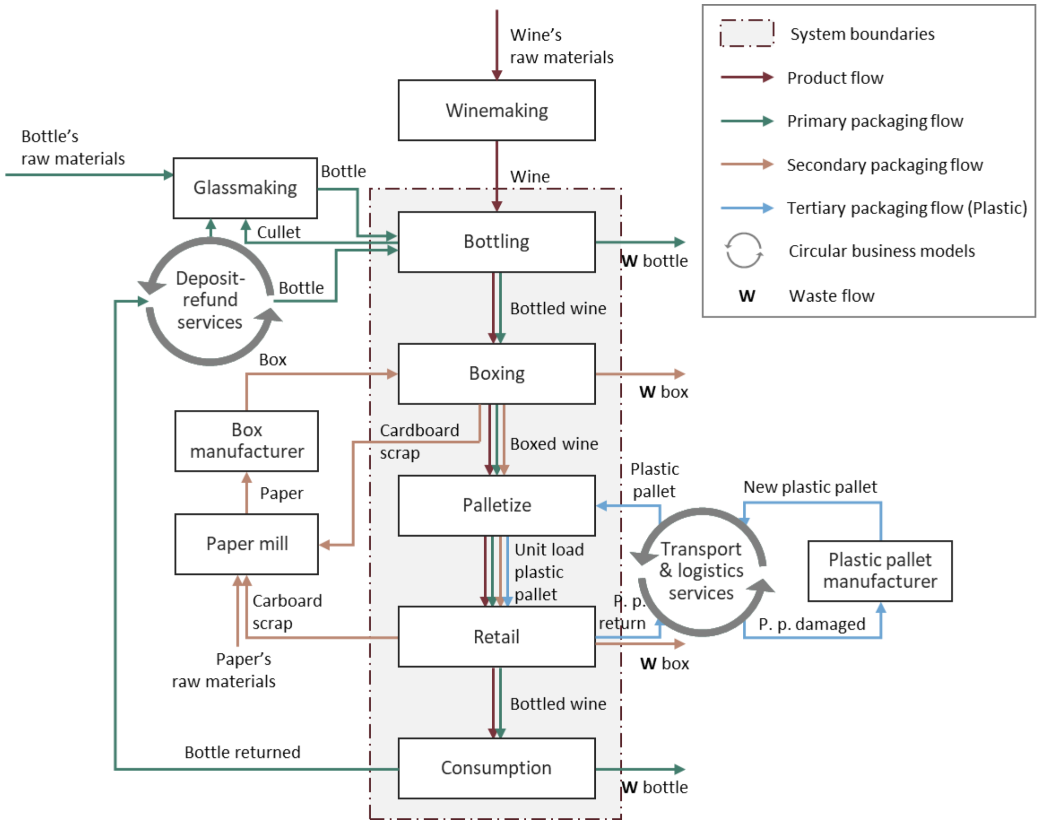

Figure 5.8: New circular configuration for primary, secondary and tertiary packaging

Cardboard box system is currently generating less waste than the other products studied, also it is commonly known as sustainable substitution of other materials. Therefore, we could not find many best practices as we did for the other types of packaging. Our suggestion is based on increasing the RO Recycle considering the technical country capacity of 89% as the maxim recycling rate (ANIR, 2018).

5.2.3.1 CBM Deposit-refund services

Glass bottles leave the system after consumption, consumers dispose of the bottle in different ways making collection difficult. Deposit-refund system is a known practice to increase collection rates and is already used in Chile for soft drinks and beers. It is estimated that it could increase the collection rate to 85% (Dictuc Greenlab, 2019). Wine bottles engage the consumer and position itself in the market, where heavier bottles are related to high-end product. Thus, marketing strategies from wineries tend to go for the increase in bottles weight, to raise the perceived value from the consumers, which is a less sustainable option. Taking into consideration our interviewees' opinions, the circular solution is different depending on the segment of the wine. We divided the market into two segments: mass consumption and premium (Annexe 10.3). The design of mass consumption wines system is based on the RO Return; a generic refillable bottle could be created that can be returned up to 5 times with a weight of 400 g. Weight has to be increased from 380 to 400 g for durability reasons (Ponstein et al., 2019). Premium wine's new configuration is based on the RO Reduce which consist of a weight reduction of 30%. A CBM should be incorporated to provide the services of collecting, sorting and cleaning the bottles. It oversees the collection of single and refillable bottles. Undamaged refillable bottles are cleaned to be used again, whereas damaged refillable bottles and single-use bottles are transformed into cullet which can be used for the manufacture of new bottles or other glass products.

5.2.3.2 CBM Transport & logistics services

The design of the wood pallets system would be based on the RO Refuse by replacing them with plastic pallets. The use of plastic pallets requires an initial investment and reverse logistics that for small wineries it is costly to implement, so the design includes a CBM called Transport & logistics services which should oversee these new operations.

5.3 Material Flow Analysis for circular configuration

The MFA for the new configuration was calculated using the same procedure than Section 5.1. The new configuration considered the incorporation of two CBM, Deposit-refund services for glass bottles and Transport & logistics services for pallets. Table 5.3 shows the parameters used to calculate the MFA for this configuration. This takes into consideration the best existing practices, thus with the current landscape, this is probably the maximum waste that is possible to reduce.

Table 5.3: Parameters to devise the new circular supply chain configurations

Loop	R#	CE concept	Glass bottles		Cardboard box	Wood pallet	Plastic pallet
			Mass	Premium			
Long	**R7**	**Recycle**	The recovery rate is 85% (Dictuc Greenlab, 2019)		The technical capacity is 89% (ANIR, 2018)		
Short	**R2**	**Reuse**	5 times (Ponstein et al., 2019)				
	R1	**Reduce**	400 g (Ponstein et al., 2019)	380 g - 30% less (Point et al., 2012)			
	R0	**Refuse**				Change to plastic pallet	
Services		**CBM**	Deposit-refund services			Transport & logistics services	

Table 5.4 shows the waste that is landfilled for each type of packaging in units and weight for the circular configuration. The details of the calculations are indicated in Annexe 10.2.2. The comparison with the current results is shown in Section 5.4.

Table 5.4: Total waste that is landfilled for the new configuration

Waste flow	# units	Weight (ton)
Glass bottle	39.342.373	14.950
Cardboard box	4.629.356	1.852
Wood pallet	0	0
Plastic pallet	0	0
Total		**16.747**

Glass bottle generates the highest amount of waste, with 14.895 ton and more than 39 million bottles per year. Cardboard box generates 1.852 ton with more than 4 million units. Plastic pallets do not generate waste, as the business model recovers 100% of the damaged pallets to recycle them.

Figure 5.9 shows the packaging intensity for the new configuration. Glass bottle intensity is illustrated in green, cardboard box in brown and plastic pallet in sky-blue. The waste reduced compared with the current system is exposed in pale grey with a dashed line.

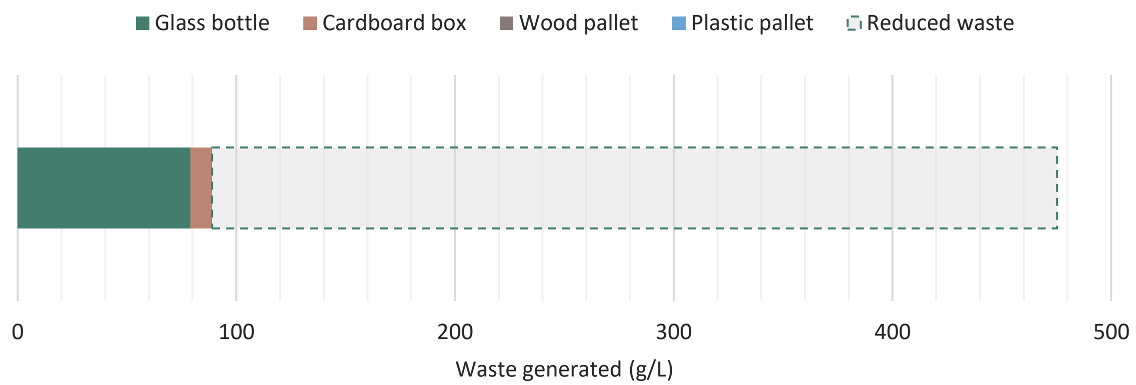

Figure 5.9: Waste generation per litre of wine consumed for the new configuration

The waste reduced is from 475 g/L from the current system to 88,8 g/L for the new configuration. Glass bottles intensity is reduced by almost five times to 79,0 g/L and cardboard box is reduced by half to 9,8 g/L. Pallet intensity is cero for the new configuration as all the wood are substituted for plastic ones that do not generate waste that ends in landfills.

5.4 Comparison of the systems flows

Figure 5.10 shows in a Sankey diagram the flows for the current and the new circular system. It shows for each type of packaging the treatment that has at the end of life. It follows the same previous colour code; glass bottles in green, cardboard box in brown, wood pallet in grey and plastic pallets in sky-blue. The shade of the colour represents the treatment of the packaging at its end of life, where a dark colour means that is landfilled, medium shade that is recycled and pale shade that is reused. The width of the flows is proportional to the weight of the packaging. The software used is SankeyMATIC where the input is shown in Annexe 10.4.

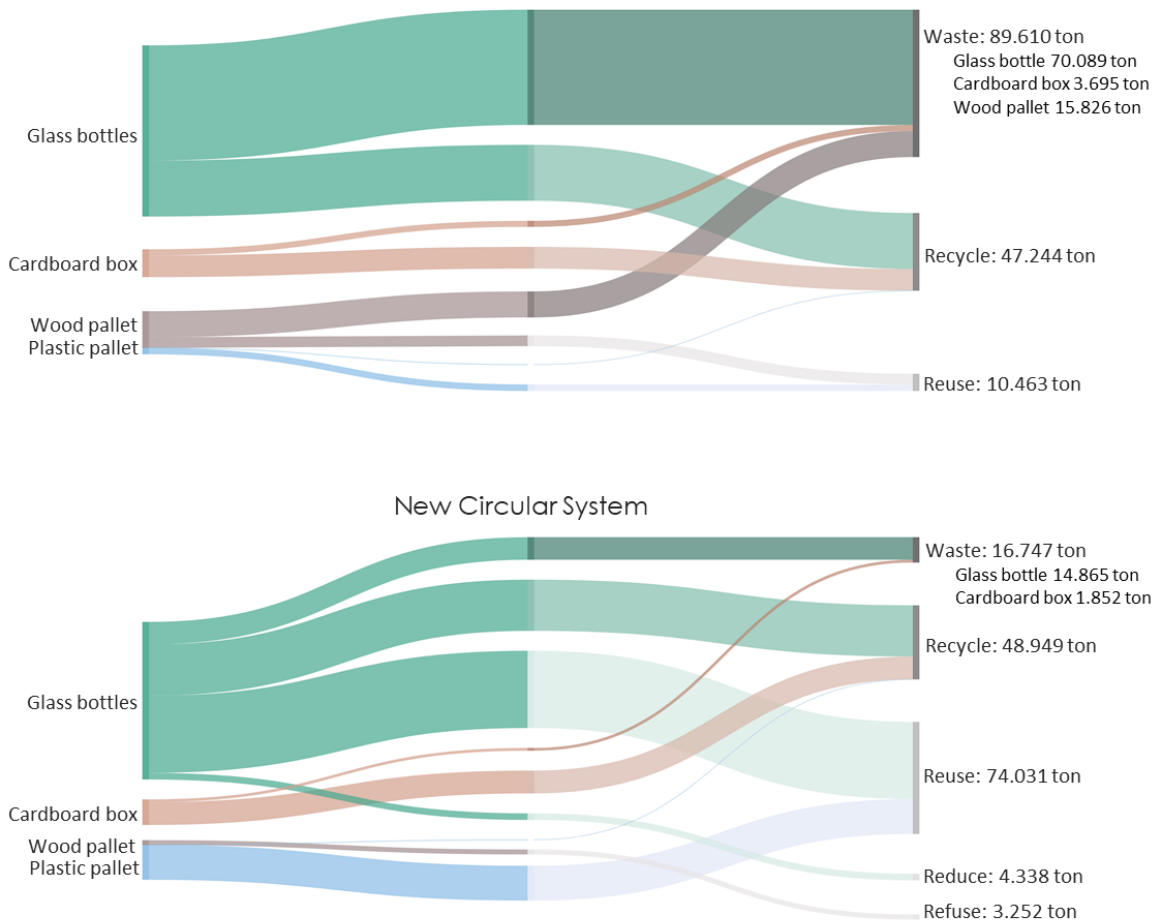

Figure 5.10: Comparison of the current and new circular system flows

Waste that ends in landfill decreases by 81% from 89.610 to 16.747 tones. This is explained by an increase of more than seven times the amount of packaging that is returned. The recycling diminishes slightly by 4% due to the substitution from wood pallets to plastic pallets. Reduce and refuse represents 5% of the total, that is the packaging that is not produced. We calculated Refuse as the difference in weight between the tons generated for the current model and new configuration. However, what is strictly happening is a substitution from one material to another with a reduction of waste because less weight of the material is needed to transport the same unit.

6 Discussion

6.1 Theoretical implications

This research was based on the ROs framework from Reike et al. (2018), they reviewed different perspectives and united the most common views in a 10R typology. We applied this framework to the case of the packaging within the Chilean wine industry. Some of the ROs were not applicable for this specific case, thus we only considered those that could be applied. We also suggested the inclusion of biological flows and services (Section 5.2.2).

We found that the ROs applicable for this case are R7 Recycle, R4 Refurbish, R2 Reuse, R1 Reduce and R0 Refuse. We found that the ROs hierarchy proposed by Reike et al. (2018) was crucial when designing and evaluating a study case; but during our research, we found that the proposed hierarchy differed in the Chilean wine packaging case, where the highest value R0 and R1 reduced a fewer amount of waste than R2 and R7 strategies. We chose to show the applicable ROs strategies for our study case in a temporal manner, following the stages of the packaging process. Figure 6.1 illustrates how Refuse and Reduce influences the process of design. Recycle affects the manufacture and reuse the packing process. Refurbish is shown as an open-ended arrow because the packaging leaves the system and is modified to have another lifecycle.

To address the biological nutrients (i.e. cardboard and wood), we incorporated the concepts from Cradle-to-Cradle (McDonough & Braungart, 2002). We consider this in Figure 6.1 as an additional loop that biological nutrients can follow. This loop takes into account that after consumption, nutrients should return to the earth and virgin materials used to manufacture new products should come from sustainable sources.

We noticed that designing a production process with circular activities is more complex than the linear model because additional services must be implemented to support the occurrence of the RO activities. We include CBM at the end of the consumption process to represent the services needed to help the nutrients to return to the system.

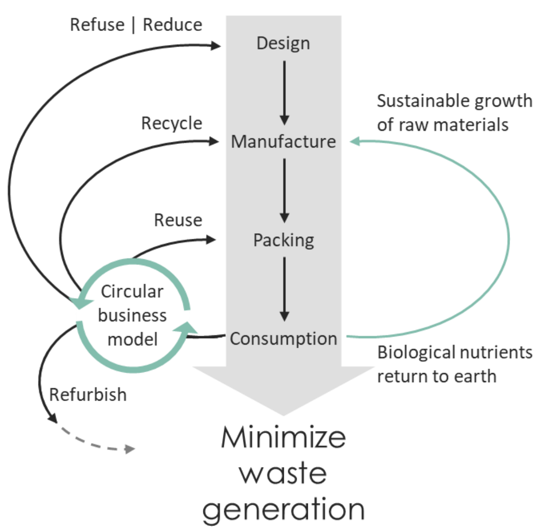

Figure 6.1: The applied framework to analyse and design circular configurations for packaging

This framework could be used to analyse a packaging system, and to assess the current waste generation. Based on best practices it is possible to suggest circular business models and estimate the reduction of waste for a specific new designed configuration.

6.2 Recommendations for the industry

The glass bottle is the packaging that generates more waste (Section 5.1.5), this was an expected result as given our assumption that a high carbon footprint relates to high waste production. Segmentation of the wine market relates high-end products with heavier bottles, this is heavily marked in emergent markets where the consumer is less educated, which is the case of the Chilean domestic market. Given the environmental and economic benefits of using more lightweight bottles, there is an interesting opportunity to educate and increase awareness among wine consumers. This could be done by invest in advertisement and campaigning in wine fairs about sustainability issues, as these activities have been used previously to change wine perception of organic and fair-trade wines. Also, common practices to educate consumers about sustainability is the incorporation of labels and champions which serve to spread the information.

The reduction of bottle weight for low-end products has traditionally been used in massive and low-cost varietal wines, mainly due to economic reasons that push for cost reduction and increase profit margins. However, the environmental benefit has not been communicated to the consumers. Environmentally friendly wine is a growing trend, but the focus has been in the product itself and has not yet expanded to its packaging. We have shown that there is an opportunity to exploit lightweight formats and use this to educate consumers about environmentally friendly packaging to differentiate within the market.

Refillable bottles are an interesting option to take into consideration as they show the highest reduction in the generation of waste (Section 5.4). This is also a more complex option than lightweight bottles, as it needs specific reverse logistics that requires the consumer to return the packaging to a certain place. Thus, increase consumer awareness and give the right incentives is essential. This model implies that bottles circle longer, ergo they need to be sturdier which implies a higher bottle weight. This is an interesting option for wines that sell many units, such as those pertaining to massive, varietal and -to a lesser extent- reserve segment. As these segments have a higher circulation of the bottle it is easier to create a unique bottle for all of them. Moreover, returnability on soft drinks has been a common practice for many years in Chile (Section 5.2.2). Although this practice has been decreasing due to economic growth, it is not a losing battle. It is still time to act to avoid losing this practice by shifting the message from 'cheaper alternative' to an 'environmentally friendly alternative'.

Regarding cardboard boxes, we could not design a reasonable CBM as Chilean practices were already the same as the best known from the worldwide leaders. The leader Chilean paper mill has incorporated storage, collection, and sorting of the recyclable material into their business units; thus, they can collect a cleaner product as they know better the operations in comparison with worldwide leaders. One CBM that we considered was to substitute the cardboard boxes with plastic ones, creating a CBM similar to those proposed for pallets, but when we validated this proposal with industry experts, they mentioned that it is unlikely to happen since it requires a high initial investment and the product might be unprotected.

We studied two materials for pallets, wood and plastic. Wood was the second packaging that most waste generated; contrary, plastic pallets generates zero waste (Section 5.1.5). Given our assumption that plastic is known for having a big environmental impact, whereas wood is seen as an environmentally friendly material, our results were unexpected. Additionally, changing from technical nutrients to biological is claimed to be a circular strategy (DelftX, 2019). Despite that wood pallets often consider multiple RO strategies such as Recycle, Repurpose, Repair, and Reuse (See Table 5.2); data shows that overall, they generate more waste compared to plastic pallets (Table 5.1).

6.3 Limitations and future research

The limitations of this research must be accounted for the quality of data, selection of boundaries and goods. Quantitative data were collected from databases and reports published by Chilean government institutions, as well as public and private associations (i.e. Wines of Chile and CENEM). Information regarding wine packaging was showed aggregated with other industries and/or combined with the packaging that is exported, therefore we made assumptions based on our interviewees' answers. We managed this limitation by triangulating the information from different sources to validate our assumptions. This limitation shows how important it should be for the Chilean wine industry to start organizing themselves and collect data to assess their current impact and improve based on analytical and scientific-based studies.

Qualitative data were obtained from semi-structured interviews, only one researcher collected and analysed the data which could lead to subjective interpretation. This was compensated by using companies reports and governmental studies to achieve data triangulation. Moreover, the interviews were made in the local language that could lead to a mistranslation; we mitigate this by having an interviewer that has compelling skills in both languages. The response of wineries executives was low, mainly because there was no direct contact and most of them were approached via email or using LinkedIn. To overcome this barrier, we contacted different persons within the same company. They usually claimed that it was an interesting study, but they did not have enough time to answer all questions or agree to a lengthy interview. Therefore, we were flexible to accept answers by audio, written or through a video-call.

This study presented an overview of the wine industry and has an exploratory character; thus, we chose to measure only one environmental impact, waste generation. In the same line, wine packaging has more elements than the ones we selected for our study (e.g. labels, cork, caps and plastic wrap); we focussed on the materials that represent the biggest proportion of the packaging, and therefore have the biggest influence for an MFA. A life cycle assessment, including all materials and several impact categories, is needed to be certain that the overall impact is reduced before running any pilot or implementing. For example, the CBM Deposit-refund system needs to consider the cleaning of bottles where water, detergents and heat are needed to carry this operation. If this is not well designed, it could lead to a disproportional increase in water use, ecotoxicity, eutrophication, use of energy, greenhouse gases emissions to mention ones. Thus, we suggest as a further study to carry a life cycle assessment using the results of our study as an input.

We assumed that the system for plastic pallets is circular and no waste is produced. This is a simplification due to the temporal boundaries of a year chosen, and because we did not include the manufacturing processes. A lifecycle assessment from cradle-to-grave is suggested to understand the flows that enter and exit the plastic pallets system.

Other types of primary packaging for wine were excluded, such as cartons, bag-in-box, aluminium cans and PET Bottles, as they are not common in the industry at this time. However, they are gaining popularity as they are more lightweight than glass bottles, but they are more complex and difficult to recycle. An interesting trade-off that is valuable for further studies considers a comparison and a market analysis for these new materials on the Chilean case.

An interesting RO that we did not include in our design is Repurpose, as it creates another lifecycle for the packaging, to estimate the demand for that product a market analysis is needed. Also, the boundaries need to be expanded to calculate the avoided products that are manufactured.

7 Conclusion

Even though Chile has shown the ambition to position itself as a leader in producing sustainable wines, sustainability issues related to wine packaging have not been addressed properly. With a lack of quantitative and scientific-based studies, we aimed for this research to study the amount of waste generation that circular business models can reduce through the supply chain. We study this using Material Flow Analysis on the case of the packaging in the Chilean wine industry for their domestic market.

The main research question that we answered was '*To what extent circular business models can decrease the waste generated from packaging in the Chilean wine supply chain for its domestic market?'*. To answer this, we divided the research into 3 parts with one sub-research question for each. The main results for each part are summarized in the following paragraphs.

1. *What is the current amount of waste generated from the packaging?*
   We studied primary, secondary and tertiary packaging from the wine supply chain. We selected one material per type of packaging that represented the biggest volume. A generic system was defined using data from interviews and documents (Section 5.1.5). The final amount of waste generated was calculated using an MFA. For the primary packaging, the selected packaging was glass bottles of a capacity of 750 ml, which generates 70.089 ton of waste per year. The cardboard box was selected as secondary packaging which generates 3.695 ton of waste per year. For tertiary packaging, we chose two materials, wood and plastic. Wood pallets generate 15.826 ton of waste and plastic pallets do not generate waste because the manufacturer company uses CE as the main value.

2. *How can circular business models affect the configuration of the supply chain?*
   We created a methodology to devise a new circular configuration which had 3 steps (Section 4.3.2): The first was to identify the ROs present in the current system, where we found Recycle for all materials, repurpose for glass bottles and wood pallet, Repair for the wood pallet, Reuse for wood and plastic pallet, and Reduce for glass bottles. The second step was to research for best practices in other industries and countries. We looked for practices that increase the ROs found and to change for RO with a higher value. Then, we validated the feasibility of these practices with experts in the industry. The third step was to define new processes and goods. The results of the new configuration are shown in Figure 5.8. The circular production process is more complex and additional services are needed to support the occurrence of RO activities. Two CBM where incorporated, a Deposit-refund services for glass bottles and transport & logistics services for pallets.

3. *What would be the amount of waste generated considering the new circular supply chain configuration?*
   We use the same procedure from sub-question 1 to calculate the flows with the new configuration devised in sub-question 2. We found that Reuse is the RO that could reduce more waste generation. Glass bottles generated 14.950 ton of waste, cardboard box generated 1.852 ton and pallets do not generate waste as wood pallets are substituted by plastic ones.

The answer to our main research question is that the extent that waste could be reduced is 81% from 89.610 to 16.747 ton per year considering our system definition, this is mainly explained by the increasing the return by seven times.

We also defined packaging intensity as the amount of packaging discarded to consume a litre of wine. The packaging intensity was 475 g/L for the current model, and it was reduced to 89 g/L in the new circular configuration.

From our research, we observed that CE does not occur spontaneously. Often our mindset is linear, therefore the design and implementation of CE strategies must be intended. The motivation could come from pressure from external stakeholders and/or visionary leaders in the companies that understood that the linear model is not applicable anymore. The pallet case implies that it is more important a systemic and comprehensive lifecycle design for a product than simply choosing a material with less environmental impact.

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10 Annexe

10.1 Semi-structured interview guide

Spanish - Original
INICIO
Agradecer
Permiso grabación

Contexto investigación: Mercado nacional vino. Envases. Botellas, cajas de cartón y pallet.

Cadena de producción
Embotellado:
¿Cuántos litros embotellan?
¿Qué botellas usan?
¿Cuántas botellas se rompen? ¿Qué hacen con este residuo?

Cajas:
¿Cuántas botellas por caja?
¿Quién es el proveedor?
¿Se rompen?

Palet:
¿Como es la unidad de pallet? ¿Dimensiones, peso?
¿Utilizan otros materiales?
¿Cuántas vueltas da?

Almacenamiento y Logística:
¿Cuál es la unidad de almacenamiento?
¿Quién transporta?
¿Cada cuánto?

SUSTENTABILIDAD - ECONOMÍA CIRCULAR
Ley REP: ¿Cómo les ha afectado la ley?
¿Qué han hecho?
¿Qué van a hacer?

MODELOS DE NEGOCIOS CIRCULARES
Retornables: Botellas, cajas(javas), pallets
Rechazar: Cajas de cartón.
Reducir: Peso botellas, peso cajas de cartón

TERMINO
¿Con quién más debo conversar?
¿Como quieres que tratemos tus datos? Decir nombre, nombrar empresa, o nada.

English - Translation
START
Greetings and thanks
Recording permission

Research Context: National wine market. packaging. Bottles, cardboard boxes and pallet.

SUPPLY CHAIN
Bottling:
How many litres do you bottle?
What types of bottles do you use?
How many bottles are broken? What do you do with this residue?

Boxes:
How many bottles per box?
Who is the provider?
Do they break?

Pallet:
How is the pallet unit? Dimensions, weight?
Do you use other materials?
How many turns does it make?

Storage and logistics:
What is the storage unit?
Who transports?
How often?

SUSTAINABILITY - CIRCULAR ECONOMY
EPR Law: How has the law affected you?
What have you done?
What are you going to do?

CIRCULAR BUSINESS MODELS
Returnable: Bottles, boxes (java), pallets
Refuse: Cardboard boxes
Reduce: Weight of bottles, weight of boxes

CLOSURE
Who else should I talk to?
How do you want us to treat your data? Show personal name, company name, or nothing

10.2 MFA assumptions and calculations

10.2.1 MFA current system

Data & assumptions			
Wine density	0,99	kg/L	https://www.aqua-calc.com
Bottled national wine sales	189	million L	(Vinos de Chile, 2017; Wines of Chile, 2019)
Bottle weight	410	g	(High executive at a large vineyard, personal communication, May 25, 2020)
Bottle capacity	0,750	L	
Box weight	400	g	(High executive at a large vineyard, personal communication, May 25, 2020)
Bottles per box	6		
Wood pallet area	1,2	m2	(High executive at a plastic manufacturer company, personal communication, March 26, 2020)
Wood pallet weight	25	kg	
Plastic pallet area	1,2	m2	
Plastic pallet weight	22	kg	
Boxes per pallet	40		(High executive at a beverage company, personal communication, May 1, 2020)
Plastic pallet share	17,2%		(CCU, 2018)
Pallet cycles per year	12		

Table 10.1: MFA current system

Process	Material	Quantity (ton)	Rate	Reference
Winemaking	Wine	186.632		
Glassmaking	Bottle	104.097	1% Losses in bottling	(High executive at a small vineyard, personal communication, April 23, 2020)
Bottling	Bottled wine	289.688		
	Cullet	1.031	99% Recycling rate	Assumption
	W bottle	10		
Box manufacturer	Box	16.926	1% Losses in boxing	Assumption
Boxing	Boxed wine	306.445		
	Cardboard scrap	161	95% Recycling rate	Assumption
	W box	8		
Wood pallet manufacturer	Wood pallet	15.826		
Plastic pallet manufacturer	Plastic pallet	4		
Palletize	Unit load wood pallet	275.416		
	Unit load plastic pallet	53.039		
Retail	Wood pallet return	6.504	30% Return rate	Assumption: only the channel supermarkets has the structure to return pallets
	W wood pallet	15.176		
	Plastic pallet return	3.959		
	Plastic pallet damaged	4	1000 Times used	(High executive at a plastic manufacturer company, personal communication, March 26, 2020)
	Cardboard scrap	13.071	78% Recycling rate	(ANIR, 2018)
	W box	3.687		
	Bottled wine	289.688		
Repair	Wood pallet repaired	5.853		
	W wood pallet	650	10 Times used	(High executive at a plastic manufacturer company, personal communication, March 26, 2020)
Consumption	Cullet	32.978	32% Recycling rate	(ANIR, 2018)
	W bottle	70.078		

Table 10.2: Total MFA current system

Waste flow landfilled	# units	Weight (ton)	Material Intensity (g/L)
Glass bottle	170.947.651	70.089	372
Cardboard box	9.237.554	3.695	20
Wood pallet	633.041	15.826	84
Plastic pallet	0	0	0
Total	**180.818.246**	**89.610**	**475**

10.2.2 MFA new configuration

Data & assumptions			
Wine density	0,99	kg/L	https://www.aqua-calc.com
Bottled national wine sales	189	million L	(Vinos de Chile, 2017; Wines of Chile, 2019)
Bottle weight S	380	g	Calculated from Table 10.5
Bottle weight R	400	g	Calculated from Table 10.5
S bottle share	25%		Assumption: Premium to luxury wines use a single-use bottle
Bottle capacity	0,750	L	
Box weight	400	g	(High executive at a large vineyard, personal communication, May 25, 2020)
Bottles per box	6		
Wood pallet area	1,2	m2	
Wood pallet weight	25	kg	(High executive at a plastic manufacturer company, personal communication, March 26, 2020)
Plastic pallet area	1,2	m2	
Plastic pallet weight	22	kg	
Boxes per pallet	40		(High executive at a beverage company, personal communication, May 1, 2020)
Plastic pallet share	100%		CBM: all wood pallets are substituted by plastic
Pallet cycles per year	12		

Table 10.3: MFA new configuration

Process	Material	Quantity (ton)	Rate		Reference
Winemaking	Wine	186.632			
Glassmaking	Bottle S	24.492	1%	Losses in bottling	(High executive at a small vineyard, personal communication, April 23, 2020)
	Bottle R	24.764			
Collection & cleaning services	Bottle R	51.013	5	Times used	(Ponstein et al., 2019)
	Cullet	33.363			
Bottling	Bottled wine S+R	285.898			
	Cullet	488	99%	Recycling rate	Assumption
	W bottle	5			
Box manufacturer	Box	16.926	1%	Losses in boxing	Assumption
Boxing	Boxed wine	302.655			
	Cardboard scrap	161	95%	Recycling rate	Assumption
	W box	8			
Wood pallet manufacturer	Wood pallet	0			
Plastic pallet manufacturer	Plastic pallet	23			
Palletize	Unit load wood pallet	0			
	Unit load plastic pallet	304.576			
Retail	Wood pallet return	0			
	W wood pallet	0			
	Plastic pallet return	23.018			
	Plastic pallet damaged	23	1000	Times used	(High executive at a plastic manufacturer company, personal communication, March 26, 2020)
	Cardboard scrap	14.914	89%	Recycling rate	(ANIR, 2018)
	W box	1.843			
	Bottled wine	285.898			
Repair	Wood pallet repaired	0			
	W wood pallet	0	10	Times used	(High executive at a plastic manufacturer company, personal communication, March 26, 2020)
Consumption	Bottled returned S	20.610	85%	Return rate	(Dictuc Greenlab, 2019)
	Bottled returned R	63.766			
	W bottle	14.890			

Table 10.4: Total MFA new configuration

Waste flow landfilled	# units	Weight (ton)	Material Intensity (g/L)
Glass bottle	39.197.042	14.895	79
Cardboard box	4.629.356	1.852	10
Wood pallet	0	0	0
Plastic pallet	0	0	0
Total	**43.826.398**	**16.747**	**89**
Reduced waste		72.863	387

10.3 Market segmentation

Table 10.5: Market segmentation

<table>
<tr><th colspan="3">Segment

2017 Volume market
(Vinos de Chile, 2017)</th><th></th><th>2017</th><th>Weight (g)
(Verallia, 2020)</th><th>2017</th><th>Weight (g)
(Verallia, 2020)</th><th>Circular configuration</th></tr>
<tr><td rowspan="3">Fighting varietal</td><td>Mass consumption</td><td>28,70%</td><td>X</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Varietal</td><td>3%</td><td>4%</td><td rowspan="2">74,61%</td><td rowspan="2">380</td><td rowspan="2">75%</td><td rowspan="2">380</td><td rowspan="2">400</td></tr>
<tr><td>Varietal top</td><td>50,20%</td><td>70%</td></tr>
<tr><td rowspan="2">Premium / Super-premium</td><td>Reserve</td><td>11,50%</td><td>16%</td><td rowspan="2">19,92%</td><td rowspan="2">500</td><td rowspan="5">25%</td><td rowspan="5">543</td><td rowspan="5">380</td></tr>
<tr><td>Premium reserve</td><td>2,70%</td><td>4%</td></tr>
<tr><td rowspan="2">Ultra-premium / Luxury premium</td><td>Grand reserve</td><td>3,10%</td><td>4%</td><td rowspan="2">5,47%</td><td rowspan="2">700</td></tr>
<tr><td>Ultra premium</td><td>0,80%</td><td>1%</td></tr>
<tr><td>Super luxury / Ultra-premium</td><td>Icon</td><td>0%</td><td>0%</td><td>0%</td><td>1000</td></tr>
</table>

X: Mass consumption is not sold in glass bottles of 750 ml

10.4 SankeyMATIC input

10.4.1 Colour code

:Glass bottle #46A88E<<
:Cardboard box #D3A08C<<
:Wood pallet #A38E8E<<
:Plastic pallet #89BCE5<<
:W Glass bottle #427D6D<<
:W Cardboard box #BA8671<<
:W Wood pallet #857979<<
:W Plastic pallet #6BA4D3<<
:Recycled Glass bottle #82BDAD<<
:Recycled Cardboard box #D6B7A9<<
:Recycled Wood pallet #B6AFAF<<
:Recycled Plastic pallet #A7C9E4<<
:Returned Glass bottle #D5E9E4<<
:Returned Cardboard box #F1E7E3<<
:Returned Wood pallet #E7E4E4<<
:Returned Plastic pallet #E1E7F6<<
:W Glass bottle #427D6D>>
:W Cardboard box #BA8671>>
:W Wood pallet #857979>>
:W Plastic pallet #6BA4D3>>
:Recycled Glass bottle #82BDAD>>
:Recycled Cardboard box #D6B7A9>>
:Recycled Wood pallet #B6AFAF>>
:Recycled Plastic pallet #A7C9E4>>
:Returned Glass bottle #D5E9E4>>
:Returned Cardboard box #F1E7E3>>
:Returned Wood pallet #E7E4E4>>
:Returned Plastic pallet #E1E7F6>>
:Reduced glass bottle #D5E9E4>>
:Refused wood pallet #E7E4E4>>
:Landfill #606060>>
:Recycle #808080>>
:Return #B9B9B9>>
:Reduce #DEDEDE>>
:Refuse #E5E5E5>>

10.4.2 Current system SankeyMATIC input

Source	[Amount]	Target
Glass bottle	[70089]	**W** Glass bottle
Cardboard box	[3695]	**W** Cardboard box
Wood pallet	[15826]	**W** Wood pallet
Plastic pallet	[0]	**W** Plastic pallet
Glass bottle	[34009]	Recycled Glass bottle
Cardboard box	[13231]	Recycled Cardboard box
Wood pallet	[0]	Recycled Wood pallet
Plastic pallet	[4]	Recycled Plastic pallet
Glass bottle	[0]	Returned Glass bottle
Cardboard box	[0]	Returned Cardboard box
Wood pallet	[6504]	Returned Wood pallet
Plastic pallet	[3959]	Returned Plastic pallet
W Glass bottle	[70089]	Landfill
W Cardboard box	[3695]	Landfill
W Wood pallet	[15826]	Landfill
W Plastic pallet	[0]	Landfill
Recycled Glass bottle	[34009]	Recycle
Recycled Cardboard box	[13231]	Recycle
Recycled Wood pallet	[0]	Recycle
Recycled Plastic pallet	[4]	Recycle
Returned Glass bottle	[0]	Return
Returned Cardboard box	[0]	Return
Returned Wood pallet	[6504]	Return
Returned Plastic pallet	[3959]	Return

10.4.3 New configuration SankeyMATIC input

Source	[Amount]	Target
Glass bottle	[14895]	**W** Glass bottle
Cardboard box	[1852]	**W** Cardboard box
Wood pallet	[0]	**W** Wood pallet
Plastic pallet	[0]	**W** Plastic pallet
Glass bottle	[33851]	Recycled Glass bottle
Cardboard box	[15075]	Recycled Cardboard box
Wood pallet	[0]	Recycled Wood pallet
Plastic pallet	[23]	Recycled Plastic pallet
Glass bottle	[51013]	Returned Glass bottle
Cardboard box	[0]	Returned Cardboard box
Wood pallet	[0]	Returned Wood pallet
Plastic pallet	[23018]	Returned Plastic pallet
Glass bottle	[4338]	Reduced glass bottle
Wood pallet	[3252]	Refused wood pallet
W Glass bottle	[14895]	Landfill
W Cardboard box	[1852]	Landfill
W Wood pallet	[0]	Landfill
W Plastic pallet	[0]	Landfill
Recycled Glass bottle	[33851]	Recycle
Recycled Cardboard box	[15075]	Recycle
Recycled Wood pallet	[0]	Recycle
Recycled Plastic pallet	[23]	Recycle
Returned Glass bottle	[51013]	Return
Returned Cardboard box	[0]	Return
Returned Wood pallet	[0]	Return
Returned Plastic pallet	[23018]	Return
Reduced glass bottle	[4338]	Reduce
Refused wood pallet	[3252]	Refuse