UNIVERSITY OF PADOVA

Department of Management and Engineering

Master of Science in Management Engineering

MASTER'S THESIS:

Circular approach to viticulture: sustainable utilisation of vine shoots to reduce waste and optimise resources

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ABSTRACT

This master's thesis focuses on the circular approach to viticulture and the sustainable utilization of vine shoots for waste reduction and resource optimization. This represents the culmination of a course of study and research that has required commitment and dedication to analyze one of the most significant challenges in today's agricultural sector.

The choice to focus on the circular approach to viticulture stems from the awareness related to the important role this sector plays in our country's economy and culture. However, climate change and increased environmental risks pose real threats to the sustainability of wine production, Therefore, it is crucial to develop innovative strategies to address these challenges and ensure a prosperous future for the sector.

In the summary, I decided to describe the personal experiences and motivations that led me to focus on this issue. I had the opportunity to connect with agricultural and viticultural realities, discovering both the challenges and opportunities associated with adopting the circular approach. During the research journey, I was able to explore the fundamental concepts of the circular economy and identify sustainable practices that can be adopted in viticulture to reduce waste and optimize resource use.

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PREFACE

In recent decades, the concept of sustainability has emerged as one of the main pillars for addressing the environmental and social challenges of our time, and it has been abused in certain contexts. In an era characterized by growing concerns regarding climate change, resource depletion, and pollution, it is crucial to adopt new approaches that place conservation and optimization of natural resources at the center. In this context, the circular approach to viticulture emerges as an innovative and promising prospect, capable of radically transforming the sector and directing it toward sustainable utilization of vine shoots for waste reduction and resource optimization.

Viticulture, which has always been side by side with human history, represents one of the most significant and ancient agricultural sectors. However, intensification of agricultural practices, increasing demand for wine products and global environmental challenges have made it imperative to rethink waste production and management methodologies in the wine industry. The dissertation presented here tackles this complex issue with courage and determination, proposing an in-depth analysis of the circular approach to viticulture and strategies to sustainably enhance the value of vine shoots to help reduce waste and protect natural resources.

Through a thorough investigation, the paper focuses on identifying and analyzing the basic principles of the circular economy and how they can be applied to the wine sector. The paper carefully examines the different stages of the viticulture production cycle, placing particular emphasis on the management of vine shoots, which, often considered waste, can instead become valuable resources within a circular economy. The sustainable valorization of vine shoots, through practices such as reuse, recyclability and reconditioning, could open up new opportunities for the wine industry, contributing not only to the reduction of waste, but also to the creation of a more resiliently sustainable economy.

In the search for innovative solutions, the thesis highlights best practices already adopted by cutting-edge wineries and also explores the possible environmental and economic benefits of adopting a circular approach to viticulture. Beyond that, obstacles and challenges that might arise in implementing such a model are identified and analyzed, and strategies to overcome them are proposed.

1. INTRODUCTION

The wine industry, with a global market of $364.25 billion in 2022 (Statista, 2022), stands as one of the most important economic sectors for global production and distribution. The wine industry continues to thrive due to its diversity and adaptation to global trends. The contribution of made in Italy to the world economy is not small; as can be seen in Figure 1.1, the Italian production market is comparable only to the French.

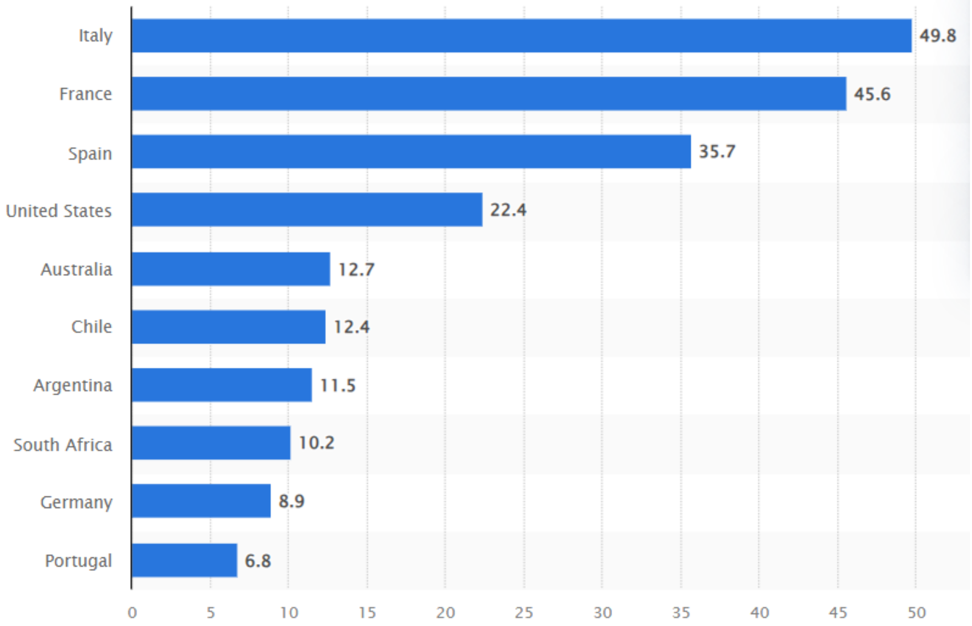


Figure 1.1: Ranking nations by wine production (hL) (Fonte: Statista, 2022)

Therefore, it is clear that Italy occupies a prestigious position within this landscape, being a major player (Figure 1.1). According to recent reports by OIV and Mediobanca (cit., 2023), Italy leads the world rankings in terms of production, surpassing the 50 million hectoliters threshold. With a focus on 2019, Eurostat found that in the European Union, there are about 11,800 wineries with an aggregate turnover of nearly 40 billion euros, 85 percent of which is concentrated in France (14.2 billion euros), Italy (11.2 billion euros) and Spain (7.8 billion euros). This picture underscores Italy's significant contribution to global wine production, embracing a wide range of varieties and styles from different wine regions. Not only leading in production, Italy ranks as the second largest wine exporter in the world, with about 22.2 million hectoliters exported according to Mediobanca reports (cit., 2023), generating a turnover of about 7.1 billion euros. This export activity is a key part of the national economy and contributes substantially to the trade balance. At the same time, domestic wine consumption places Italy as the third largest global consumer, with a volume of about 24.2 million hectoliters. This figure 1.1 underscores the crucial role of wine in the Italian cultural and social sphere, where it constitutes a fundamental element of tradition and daily life.

The Italian wine industry is characterized by the presence of numerous wineries and vineyards, distributed in different regions of the country. The indigenous varieties and quality of Italian wines are internationally recognized, attracting a large market of consumers and wine lovers from all over the world, confirming their competitiveness. (Mariani et al., 2005)

The wine economy in Italy is not only related to production and export, but also involves complementary sectors such as food and wine tourism and agritourism (Garibaldi, 2021). Italian wine regions are popular destinations for tourists, offering tasting experiences, visits to wineries, and discovery of local traditions related to wine and cuisine.

The wine industry thus represents a strategic lever for the Italian economy, generating employment, territorial development and added value both nationally and internationally. Italian wine is appreciated and sought after in international markets for its authenticity, thus helping to consolidate Italy's reputation as a major player in the wine industry globally (Mariani et al., 2005)

In this respect, an initial analysis of the data published by Federvini shows that 55.0 percent of wine is held in northern Italian regions, predominantly Veneto (Figure 1.2).

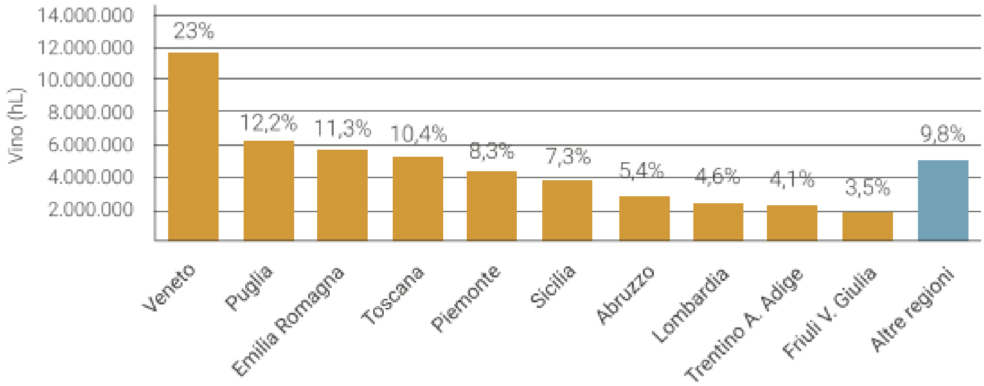


Figure 1.2: Ranking Italy's regions by wine production (Fonte: Statista, 2022)

The Veneto region has an impressive production concentrated in a single type of product: about 80 percent of Prosecco DOC is bottled in the region, and the entirety of the Denominazione di Origine Controllata e Garantita (DOCG), which emphasizes the origin and quality of the wine produced in a certain territory. This recognition of quality is also confirmed by a constantly expanding vineyard area, which includes about 36,700 hectares of Glera grapes. Between 2009 and 2022, there was a significant increase in applications for planting rights, which increased from 945 hectares to 3900 hectares. This area now accounts for about 40 percent of the total regional vineyard area and reflects the ongoing commitment to expanding and optimizing Prosecco production. This significant growth testifies to the economic and cultural importance of Prosecco within the region.

In the context of Prosecco appellations, it is essential to mention Prosecco DOCG, a higher quality wine category than Prosecco DOC. However, Prosecco DOCG constitutes about 10 percent of the total production in Veneto. This type of Prosecco is produced exclusively in the Valdobbiadene-Conegliano and Colli Asolani areas. Together with Prosecco DOC, these wines have reached an export share of 70 percent by 2022, according to Federvini's trend analysis based on the DOC Protection Consortium. This remarkable export rate, along with numerous other factors directly related to production, has a major impact on sustainability-related aspects, as shown by recent LCA studies in the wine world (Tassielli et. al., 2003; Nicoletti et al., 2003; Happonen et al, 2021) Within the wine production cycle, even the agricultural phase of the vineyard generates a considerable environmental impact, not to mention that there would be to focus attention also in the winery focusing on the impact related to CO2 production and energy consumption directly related to the fermentation process (Arzoumanidis et al., 2014; Petti et al., 2015; Woolf et al., 2010, Bietresato et al., 2023).

Unlike winery activities, which can be scheduled and placed in specific time slots according to business needs, vineyard activities follow the cycle of nature and pose numerous constraints that need to be identified, quantified, and managed in the best possible way. Among these is the vegetative phase, which produces an immense amount of organic matter valuable to the circular economy not only of the plant but, nowadays if properly managed, also of the farm.

In response to these challenges, this thesis aims to examine in detail the potential for the valorization of agricultural byproducts derived from viticulture, with a particular focus on vine shoots. These by-products, generated through vineyard pruning, are a valuable resource with the potential to contribute significantly to the circular economy. Through the application of the 3Rs model - Reduce, Reuse, Recycle - it is evaluated to create a continuous cycle of materials and products, making the most of available resources and minimizing waste.

In the context of this research, the main focus will be on exploring opportunities for energy valorization of vine shoots, agricultural by-products that result from vineyard pruning. These materials represent a promising resource for the production of renewable energy, thus helping to reduce waste and promote sustainable development within the wine industry with a focus on the Veneto industry. A crucial aspect of the investigation will be the evaluation of the techno-economic feasibility of using vine shoots as a renewable energy source. In particular, the thesis pays special attention to energy valorization through the combustion process, which exploits the calorific potential of the vine shoots. The thermal benefits obtained from this process can be used as a source of thermal energy, as fuel, for industrial processes. In addition, the adoption of low-carbon combustion practices could contribute to the reduction of dependence on fossil fuels.

A specific case study will be analyzed to concretely demonstrate the effectiveness of energy utilization of vine shoots. This case study will focus on the establishment of a pilot-scale plant, where vine shoots will be used in a boiler combustion process. Detailed evaluations of the plant's performance will be made, including energy efficiency, as measured by the production of renewable energy per unit of vine shoots used, the reduced carbon emissions achieved compared to fossil fuel alternatives, and the economic feasibility of the entire process, considering implementation costs, maintenance, and impact on farm revenues.

In addition to this, an assessment will also be made of how the approach to the energy valorization of vine shoots could have a significant impact on the wine industry and the entire Veneto region. This is because not only could it contribute to renewable energy production and the reduction of greenhouse gas emissions, but it could also create new economic opportunities, including jobs in the renewable energy industry and greater economic sustainability for wineries.

Ultimately, the detailed analysis of the energy utilization of vine shoots through the proposed case study will provide a clear and concrete overview of the possibilities of using this resource for renewable energy production. This can help promote more sustainable development in the wine industry in the Veneto region and could have positive implications for the entire energy and environmental sector.

In conclusion, comparisons with some and strategies to promote the adoption of the circular economy in the wine sector are proposed, involving key players in the sector, such as wine producers, local institutions and interested companies.

2. ANALYSIS OF THE SCIENTIFIC LITERATURE

2.1. SUSTAINABILITY AND THE CONCEPT OF CIRCULAR ECONOMY

The definition of sustainability is rooted in the concept of "sustainable development" outlined in "Our Common Future" published in 1987 by the United Nations World Commission on Environment and Development. According to this definition, sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Siebrecht, 2020). This definition introduces the ethical principle of intergenerational equity, emphasizing the right of future generations to have access to natural resources.

Later, during the Rio Earth Summit in 1992, Agenda 21 officially outlined the multidimensionality of the concept of sustainability (Silvestri, 2020), defining it as: "economically sound, ecologically sound and socially equitable development". This also introduced the economic dimension of sustainability as advocated by the Ministry of Environment, Land and Sea Protection in the V.I.V.A project (DNV, 2019)

In concepts describing systems, sustainability is instead an objective property of an individual agricultural system that meets different, perhaps even conflicting, goals over time ("goal-oriented") (Siebrecht, 2020). Sustainable agriculture has several goals (e.g., meeting human needs for food, feed and grain, improving environmental quality, sustaining economic viability).

The idea of sustainable agriculture, which has gained prominence since the 1987 Brundtland Report, shares a common feature with the concept of circular economy: both are proposed to address environmental challenges and promote sustainable development globally. However, both sustainable agriculture and circular economy present challenges in their use and implementation. Sustainable agriculture is considered a vague and ambiguous concept, while the circular economy is defined by the Ellen MacArthur Foundation as "an economic organization designed to be self-regenerating, based on the division of material flows into two types: biological ones that can be reintegrated into the biosphere and technical ones that can be revalued without entering it". Both concepts call for a systemic, collaborative and innovative approach by involving governments, companies, institutions and society as a whole to achieve a more efficient, resilient and environmentally friendly economy (Siebrecht, 2020).

From which one could cite Boulding (1966), who was one of the pioneers in presenting the circular economy paradigm as a long-term economic system that aims to reconcile growth, sustainability and waste reduction. Later, O'Rorke (1988) took up and refined this concept by introducing the preventive approach, coining the term "pre-cycle." The latter represents a set of actions to be taken in the early stages of a product's life cycle, aimed at reducing or eliminating the generation of waste, rather than focusing on its subsequent disposal.

In the industrial context, minimizing waste in production and maximizing the life cycle of products has been considered the main objective of circular economy logics. An analysis of the scientific literature offers interesting insights related to the concepts of circular economy and sustainability aspects.

Especially in the last decade, where there is a growing sense of urgency to address the issue of global resource depletion, increasing amounts of waste and greenhouse gas emissions, consequences of current models based on a linear approach of "take, produce, discard" (Zaman et al., 2013).

Such a linear approach is consistently based on turning natural resources into valuable products and, after a while, they are considered garbage and are disposed of. In such a view, several solutions have arisen to contain the amount of waste, including recycling and upcycling. In the case of recycling, several applications can be found in industry, and wine, including the recycling of corks from cork. Upcycling on the other hand, individual and sustainable sequence, which is much talked about in the field of fashion. The perfect mix of "upgrading" and "recycling." Upgrading means adding value, and recycling means reusing. In simpler terms, upcycling is the practice of taking something that is disposable and turning it into something of greater value. Therefore, when we upcycling, we create something better from what is already available. Upcycling counteracts the argument that an object has no value once it is disposed of or must be destroyed before it can re-enter a new circle of production and value creation.

In "Plastic Bags: Living with Rubbish," Hawkins (2001) argues that disposal is the logic of mass production: "The mass production of objects and their consumption depend on the widespread acceptance, and even enjoyment, of replaceability; the replacement of the old, the broken, the unfashionable with the new. A motto of upcycling could be: Throw nothing away. There is no "Plan(et) B."

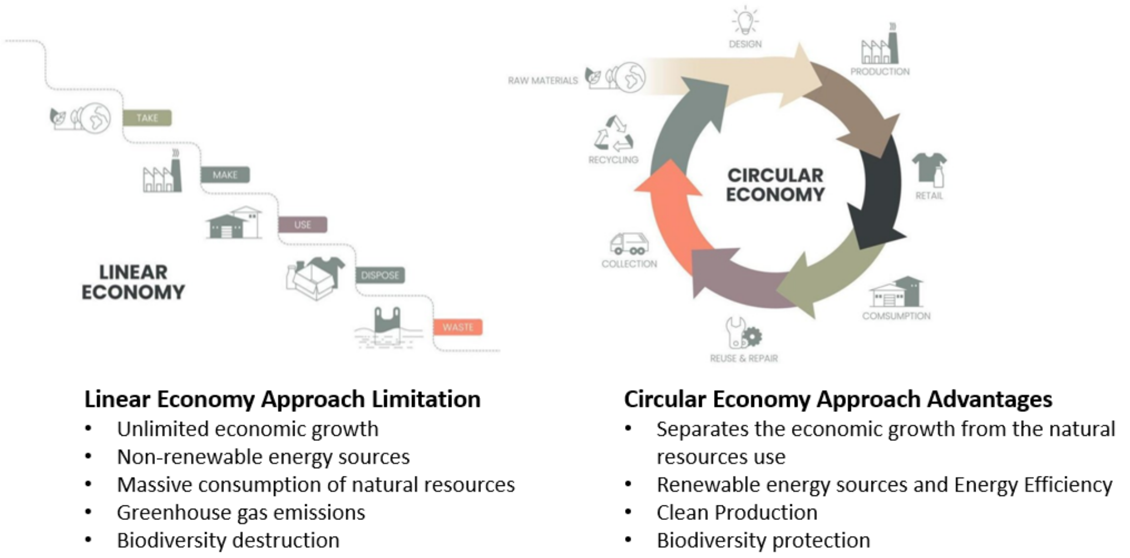
Upcycling processes and upcycled products demonstrate the interrelatedness of old and new and even dissolve "old" and "new" as distinct categories in a way that is relevant to our general understanding of creativity.

With this in mind, a model, called the 3Rs, is recognized as playing a key role in optimizing resource use and reducing environmental impacts. Through reduction, reuse and recycling, it is possible to create a more sustainable economic system in which materials and products circulate continuously, reducing dependence on virgin resources and minimizing waste.

As mentioned above, the application of methods suitable for reduction, recycling or/and reuse must be coordinated by considering all major areas of a business. Given that this linear system is causing serious damage economically, environmentally and socially, and precisely to restore balance and harmony, the concept of sustainable development (Lozano, 2008) and circularity was introduced.

Therefore, a circular economy system requires the design and implementation of business models that are based on extracting as much value as possible in the process.

The linear take-make-dispose model, therefore, is no longer sustainable, which is why the transition to a circular economy has been promoted. This new production and consumption model involves sharing, borrowing, reusing, repairing, reconditioning and recycling existing materials and products, thus minimizing waste and resource use. In this way, it is possible to extend the life cycle of products: once they have completed their function, the materials of which they are composed are in fact reintroduced, where possible, into the economic cycle and thus reused within the production cycle, generating further value.



Linear Economy Approach Limitation
- Unlimited economic growth
- Non-renewable energy sources
- Massive consumption of natural resources
- Greenhouse gas emissions
- Biodiversity destruction

Circular Economy Approach Advantages
- Separates the economic growth from the natural resources use
- Renewable energy sources and Energy Efficiency
- Clean Production
- Biodiversity protection

Figure 2.1: Potential Implications in the Transition from Linear to Circular Economy (Macdonald, 2022)

Very helpful in this is the Circular Business Model, an innovative and sustainable approach to business management that aims to create economic, social and environmental value by maximizing resource efficiency and reducing waste. Therefore, the difference from the traditional linear "take, produce, consume, discard" model, the circular business model promotes a "take, produce, reuse, recycle" philosophy (Figure 2.1).

Among the business models adopted by sustainable companies, some significant examples can be mentioned:

1. Extended Producer Responsibility (EPR): This model requires producers to be responsible for the treatment or disposal of products after their use by consumers, thus incentivizing waste prevention at the source and the design of greener products. EPR also encourages the achievement of recycling and materials management goals.

2. Product Service System (PSS): This model provides customers with a set of products and services that meet their needs more comprehensively than the traditional product-only focused approach. It aims to provide added value to products by including services that extend their life cycle and reduce material and energy consumption in the design phase.

3. Regeneration and reuse: These concepts form the foundation of circular business and are two techniques that allow some products to be put back into circulation without starting a new production cycle. Remanufacturing requires advanced technical skills and developed technological infrastructure, as it involves the reconditioning of products, thus enabling them to be reintroduced into the market as second-hand products.

The main concepts encapsulated in these circular business models involve Circular Design, Extended Life Cycle, Service Economy, Collaboration and Synergy, and Consumer Involvement, which we find in the product LCA (e.g., of the individual bottle). Therefore, a circular business model can help improve Life Cycle Analysis (LCA) in an organization. The circular approach aims to minimize waste, optimize resource use, and reduce the overall environmental impact. These goals align well with the goal of improving Life Cycle Analysis, which assesses the environmental impact of a product or service throughout its life cycle, from raw materials to production, use, and end of life.

Special attention is given to new economic opportunities for the winery, such as the creation of by-product products (e.g., cosmetics from grape pigment) that can be sold or used to diversify the company's portfolio.

Creating more value for the customer, including internally as an associate, in the first case to offset the environmental impact de product. In the second, for example, from the reuse of by-products thus a process efficiency.

Therefore, LCA, by evaluating the entire supply chain, makes each participant a stakeholder.

This form of LCA is useful and effective for defining solutions for integrated supply chain optimization and design (e.g., supply chain optimization or design support) and for the eventual formulation of improved decision-making choices. Correlation to the promotion of sustainability and the achievement of global goals set by the United Nations is highlighted.

Figure 2.2: List of 17 SDGs

The Life Cycle Assessment (LCA) approach to environmental sustainability aligns with the goal of Sustainable Development Goal (SDG) number 12: "Ensuring Sustainable Patterns of Production and Consumption" (Figure 2.2). LCA assists in identifying and reducing negative environmental impacts, enabling businesses and policymakers to make informed decisions to enhance the environmental sustainability of their activities, efficient management, and waste reduction.

Similarly, LCA is an important tool for measuring greenhouse gas emissions associated with a product or process and identifying actions or measures to contribute to climate change mitigation, in line with SDG number 13: "Take Urgent Action to Combat Climate Change and Its Impacts."

Successful implementation of a circular business model often requires the involvement of various stakeholders, such as suppliers, customers, vineyard owners, and local institutions. This cooperation can promote greater awareness of the importance of resource efficiency and environmental sustainability, which could also influence consumer behavior towards more sustainable choices, thereby improving the image and reputation of companies in the eyes of consumers, business partners, and stakeholders. Demonstrating commitment can increase consumer trust and attract a more environmentally conscious audience for their consumption choices. This can translate into a competitive advantage, allowing companies to differentiate themselves in the market and attract new customers by diversifying their sources of income through the creation of new value streams. For example, as previously mentioned, the implementation of recycling and recovery activities could lead to the creation of complementary product lines, such as accessories or products for specific industries. This diversification can increase sales opportunities and reduce dependence on a single product or market. Additionally, in many countries, businesses that adopt circular business models can benefit from government incentives and subsidies. These incentives may include tax benefits, favorable financing, or specific support programs for transitioning to a circular economy. Leveraging these opportunities can facilitate the transition to a circular business model (e.g., PNRR or Industry 4.0) in the wine industry.

Organizations aiming to adopt the circular economy model must implement new types of business models, rethink value propositions, and develop value chains that offer cost efficiency, production effectiveness, and achievable business performance (Rashid et al. 2013; Schulte 2013). Consequently, research on circular economy-related business model innovation has received increasing attention in the past five years (Diaz Lopez et al. 2019). Despite the importance of the concept of a circular business model, there is a notable lack of clarity regarding its theoretical conceptualization and its position in economic and operational literature (Geissdoerfer et al., 2020).

2.2. SUSTAINABILITY IN THE WINEMAKING CONTEXT

So far, it has been observed how concepts related to the circular economy are increasingly garnering interest from both businesses and end consumers. Nowadays, sustainability is considered a key element in any contemporary supply chain (Govindan 2018; Bai, Sarkis, and Dou 2017). However, these concepts become less clear when applied to the wine supply chain. The initial absence of a common definition of sustainable viticulture and winemaking, as well as the lack of a shared vision on the methods to achieve sustainability, leads to confusion, both among wineries and consumers (Szolnoki et al., 2011). To define the concept of sustainability applied to viticulture and wine production, both the International Organisation of Vine and Wine (OIV) and the International Federation of Wines and Spirits (FIVS) have developed sustainability guidelines, namely the Guidelines for Sustainable Viticulture (OIV 2008) and the Global Wine Sector Sustainability Principles (FIVS 2016).

The adoption of sustainable practices in the wine sector pertains to environmental protection, the cost-effectiveness and replicability of production processes, as well as the respect for the rights and dignity of individuals. The three environmental, social, and economic dimensions, also known as the "triple bottom line," are considered in relation to each other, integrating and reinforcing one another (Correia, 2019). Furthermore, the goal is to have a positive impact on the community and the region, promoting social responsibility and territorial identity.

This approach can address the contribution of the wine supply chain, where it has been found that the wine supply chain accounts for 0.3% of the total annual global GHG emissions (Rugani et al., 2013), a significant figure for a single product category. It is evident that wine companies must adopt sustainable practices to meet the goals set by the Agenda 2030 (Figure 2.3) and to maintain competitiveness in the markets, especially at the international level (Scidev, 2019).

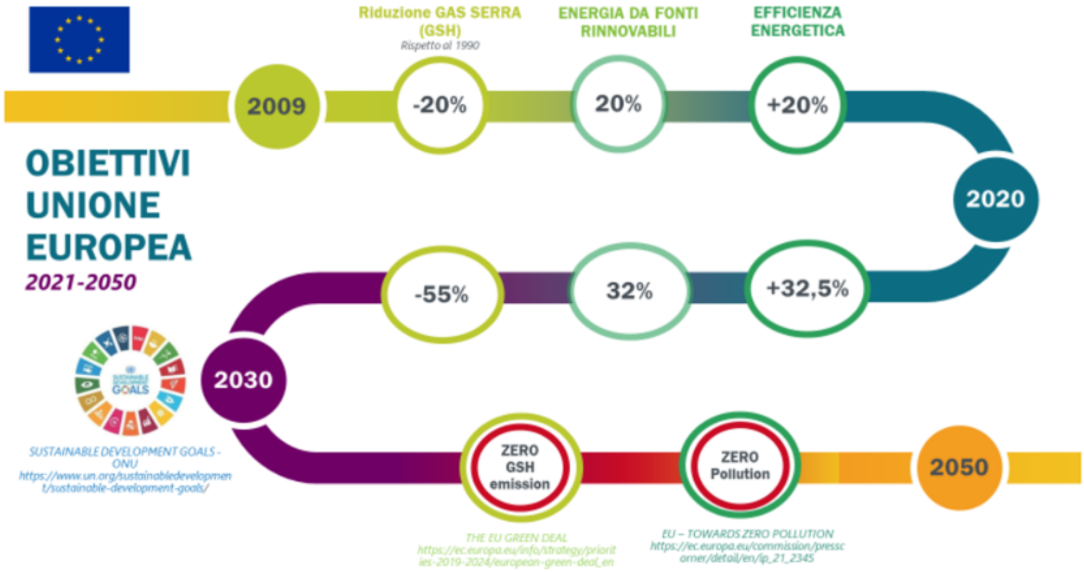


Figure 2.3: Roadmap for European Decarbonization Objectives by 2030 and 2050

From the reading of the article "What Is Sustainable Agriculture? A Systematic Review" (Velten et al., 2015), it is evident that the primary focus in achieving sustainable agriculture has, so far, been directed towards solutions centered on farm technology. The most frequently mentioned strategies are the economy-based strategy and adaptive management, with the most suggested area being that of management and technological solutions. Simultaneously, most statements regarding action contain recommendations or prescriptions on which technologies, management practices, resource types, crop varieties, etc., should be used and how if one intends to practice sustainable agriculture. The emphasis on farm-level measures is also highlighted by the fact that about two-thirds of scientific publications only consider the agricultural production level when discussing sustainable agriculture, while only one-third of publications adhere to the call to look beyond the farm gate to address sustainability issues in agriculture (Velten et al., 2015).

In this context, there has been a growing number of publications in the field and spontaneous research and educational programs focusing on sustainability themes (Pomarici & Vecchio, 2019, Costa J. M. et al., 2022) (Figure 2.4).

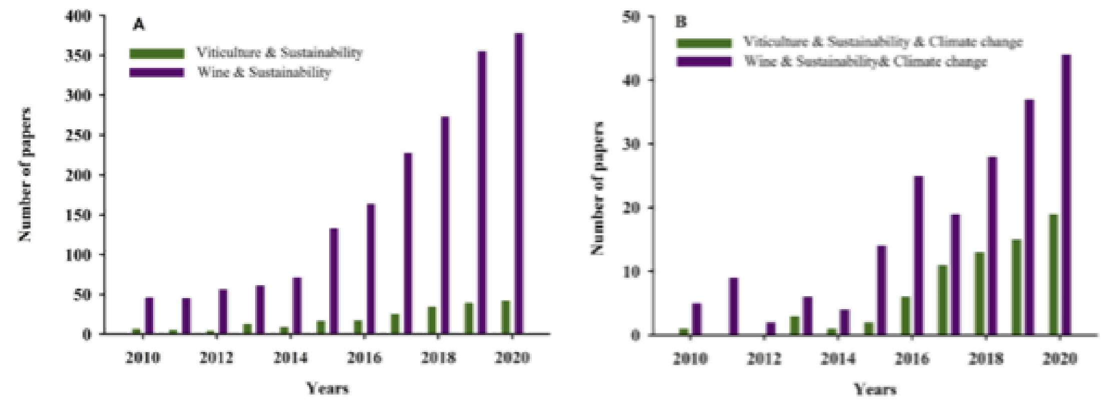


Figure 2.4: Numbers of publications on sustainability in viticulture and wine in the last decade.

Unfortunately, sustainability in the wine industry has not yet become a priority for many wineries, despite the demonstrated benefits of adopting sustainable practices for market competitiveness and promoting social well-being. Recent research (Corbo et al., 2020) aimed at monitoring Italian wine consumers has shown that more than 72% of them are interested in the topic.

To promote the adoption of sustainable practices, it is essential to consider the implementation of policies and regulations that encourage sustainability in the wine industry from a circular economy perspective.

From an initial analysis of the literature on the circular economy in the wine sector, there is significant discussion about Sustainable Waste Management, where it is crucial to adopt a sustainable approach of "Reduce and Recycle" (Yang et al., 2021). This means promoting recycling and material valorization rather than disposal, thereby reducing environmental impact and enhancing resource efficiency.

An alternative example can be seen in the reWINE experiment (Figure 2.5), which has successfully demonstrated the feasibility of a sustainable system for reusing glass bottles in the Catalan wine industry.

A detailed analysis of the results revealed that the reuse of bottles could reduce the carbon footprint of the wine sector in Catalonia by up to 28%. The savings from reused bottles are estimated to be equivalent to 1.7 to 2.6 kg of CO2 per bottle after eight reuses (seven washes).

Figure 2.5: Glass Workflow in the reWine Project

Therefore, one of the key pillars of the circular economy in agriculture is waste reduction or valorization. This can be exemplified by agricultural by-products, such as grapevine cuttings in the viticultural sector. These materials can be transformed into useful resources rather than being disposed of, contributing to reducing environmental impact and maximizing available resources (Pizzol et al., 2021).

However, a crucial aspect is the technical and economic research and evaluation of agricultural by-products. The literature provides ample room and various case studies (Devesa-Rey et al., 2011; Milano, 2012; Scientifici et al., 2018) indicate the possibility of using grapevine cuttings as a source of renewable energy. However, further studies are essential to assess effectiveness, environmental impact, and potential industrial applications.

Adapting a development and technological improvement plan to successfully implement the circular economy in the viticultural sector is crucial (Siebrecht, 2020). For example, boilers with specific technical adjustments can enable the use of grapevine cuttings as renewable fuel, reducing pollution, maximizing energy efficiency, and promoting local collaboration (e.g., district heating).

Another example can relate to the allowed alternative uses (D.M. 27/11/2008), where, at present in Italy, upcycling is not yet considered in the biopolymers industry. The high carbon content makes grape pomace the ideal substrate for biopolymer preparation.

In the perspective of creating continuous material and product cycles, it is fundamental to minimize the use of available resources. By valorizing agricultural by-products and integrating them into new production phases, the dependence on finite resources can be reduced, such as through grapevine cutting composting (Cavalaglio et al., 2007) or using grape pomace for fertilization (Beni et al., 2005). These various techniques, which are widely recognized, are scattered across the Italian territory, involving individual companies in these research and development initiatives.

In the Italian viticultural context, various successful circular business models can be found, typically targeting large groups rather than SMEs. Among these, the Caviro Group stands out as it holds approximately 8.5% of Italian grapes (Caviro, 2022). To pursue greater sustainability, the group has developed an ambitious plan for the 2022-2025 period. Led by a dedicated Sustainability Management Team, it focuses on three main objectives:

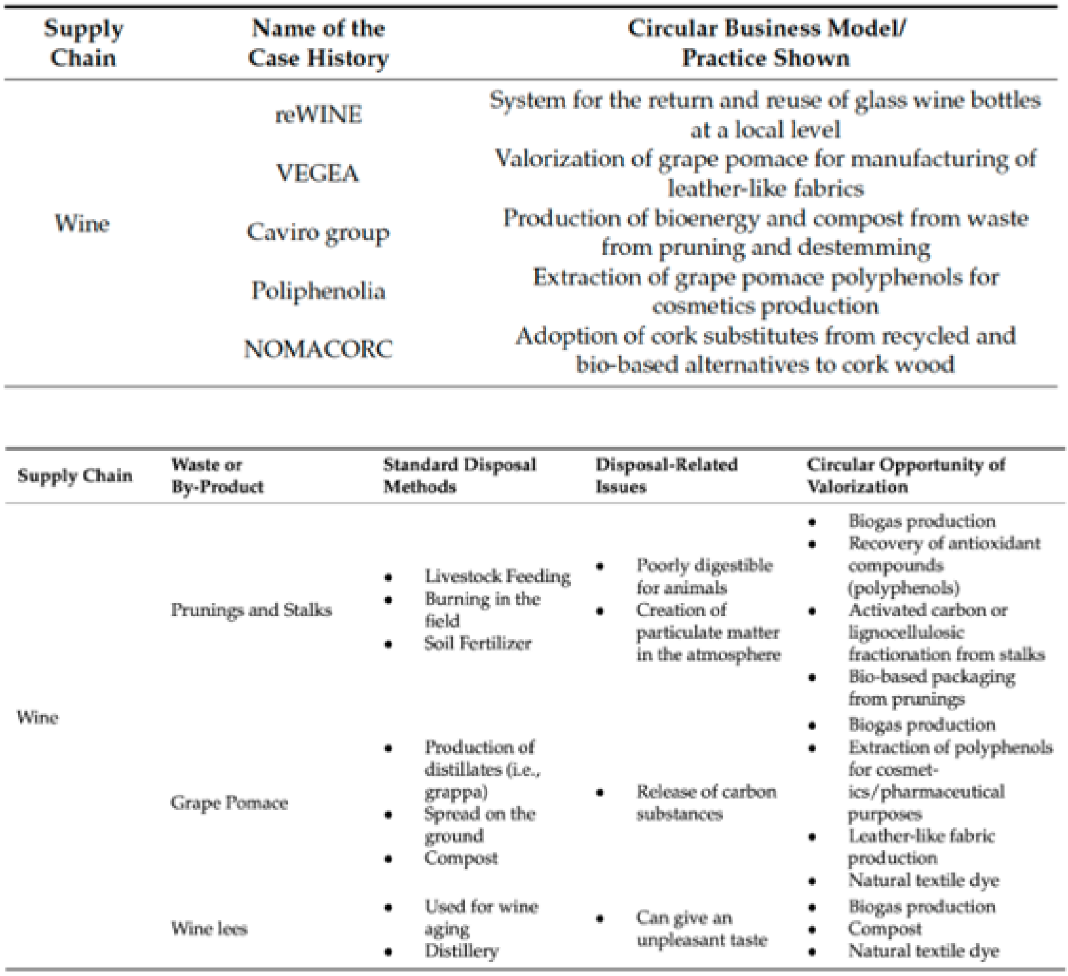
1) Integrating Sustainability Planning with the Industrial Plan through the classification of investments by ESG clusters using dedicated and potential information codes to classify revenues and costs in the future.

2) Promoting sustainability in the vineyard through the drafting and dissemination of a shared protocol that guides the actions of viticulturists towards land protection and resilience to climate change.

3) Strengthening business continuity through communication and training activities.

For instance, in terms of the circularity of the production cycle, the Caviro Group inaugurated in 2022 a natural amendment plant (ACFA) with an annual production capacity of 50,000 tons, obtained by recovering clippings and green waste prunings from public spaces and residues from the agri-food sector. Compared to chemical fertilizers, this product has a lower cost and provides nourishment to the soil, allowing for a reduction in chemical fertilizers of up to 50% if used in the long term. This project stems from the Research & Development initiative "Black to the future - Biochar and compost as soil amendment," which involves four European countries (Italy, Spain, Belgium, and Cyprus) and aims to test the potential of a new amendment dedicated to enriching soils with organic matter and combating desertification and climate change through CO2 sequestration in the soil. "Black to the future" was financed by EIT Food - European Institute of Innovation and Technology.

In Figure 2.6, other business models discussed in the literature are presented:



Supply Chain	Name of the Case History	Circular Business Model/ Practice Shown
Wine	reWINE	System for the return and reuse of glass wine bottles at a local level
	VEGEA	Valorization of grape pomace for manufacturing of leather-like fabrics
	Caviro group	Production of bioenergy and compost from waste from pruning and destemming
	Poliphenolia	Extraction of grape pomace polyphenols for cosmetics production
	NOMACORC	Adoption of cork substitutes from recycled and bio-based alternatives to cork wood

Supply Chain	Waste or By-Product	Standard Disposal Methods	Disposal-Related Issues	Circular Opportunity of Valorization
Wine	Prunings and Stalks	• Livestock Feeding • Burning in the field • Soil Fertilizer	• Poorly digestible for animals • Creation of particulate matter in the atmosphere	• Biogas production • Recovery of antioxidant compounds (polyphenols) • Activated carbon or lignocellulosic fractionation from stalks • Bio-based packaging from prunings
	Grape Pomace	• Production of distillates (i.e., grappa) • Spread on the ground • Compost	• Release of carbon substances	• Biogas production • Extraction of polyphenols for cosmetics/pharmaceutical purposes • Leather-like fabric production • Natural textile dye
	Wine lees	• Used for wine aging • Distillery	• Can give an unpleasant taste	• Biogas production • Compost • Natural textile dye

Figure 2.6: Some examples of successful circular business models

The choice of the Caviro Group to invest in the circularity of the production cycle confirms how the forefront of sustainability research today is increasingly represented by circular economy business models, which keep products and materials in use for as long as possible to extract maximum value from them (Sehnem et al., 2020).

The example of the Caviro Group illustrates how circularity in the production cycle can be achieved through a well-integrated sustainable development plan within the company's operational plan, creating synergies across ESG environments. Being a cooperative, the application of this philosophy was probably facilitated by the corporate policy. In contrast, in more rural and fragmented contexts, as highlighted by the Veneto Agricoltura experiment (Veneto Agricoltura, 2010), the challenge is involving the local community.

Engaging the actors in the Prosecco DOCG supply chain of Valdobbiadene is essential to address the challenges related to the circular economy and ensure the success of energy valorization and environmental sustainability initiatives. Collaboration among producers, supply chain operators, and local authorities is crucial for achieving integrated management of by-products, waste reduction, and the promotion of sustainable practices. This collaboration involves sharing information and best practices or mutual support in managing by-products and implementing circular economy practices. For instance, producers can collaborate with supply chain operators to ensure that by-products are collected and used optimally (Cavalaglio et al., 2007).

Therefore, a circular approach can support the reduction of the negative impact attributed to the wine supply chain. It has been observed that the wine supply chain contributes to 0.3% of the total annual global greenhouse gas (GHG) emissions (Rugani et al., 2013), a significant figure for a single product category. This is why in recent years, wine companies have started to calculate the carbon footprint of their production cycles to identify critical points for emissions reduction. The carbon footprint, or carbon footprint inventory (also known as GHG inventory), is a measure that expresses in CO2 equivalent the total greenhouse gas emissions directly or indirectly associated with a product, organization, or service. According to Vázquez-Rowe, there are several factors that influence the results of a Carbon Footprint analysis, and they are not always evaluated appropriately.

Based on a comparison with scientific literature on Carbon Footprint and considering the production process as depicted in Figure 2.7, the international average for producing a generic 0.75L wine bottle is approximately 1.95 kg CO2 eq. (Rugani et al., 2013).

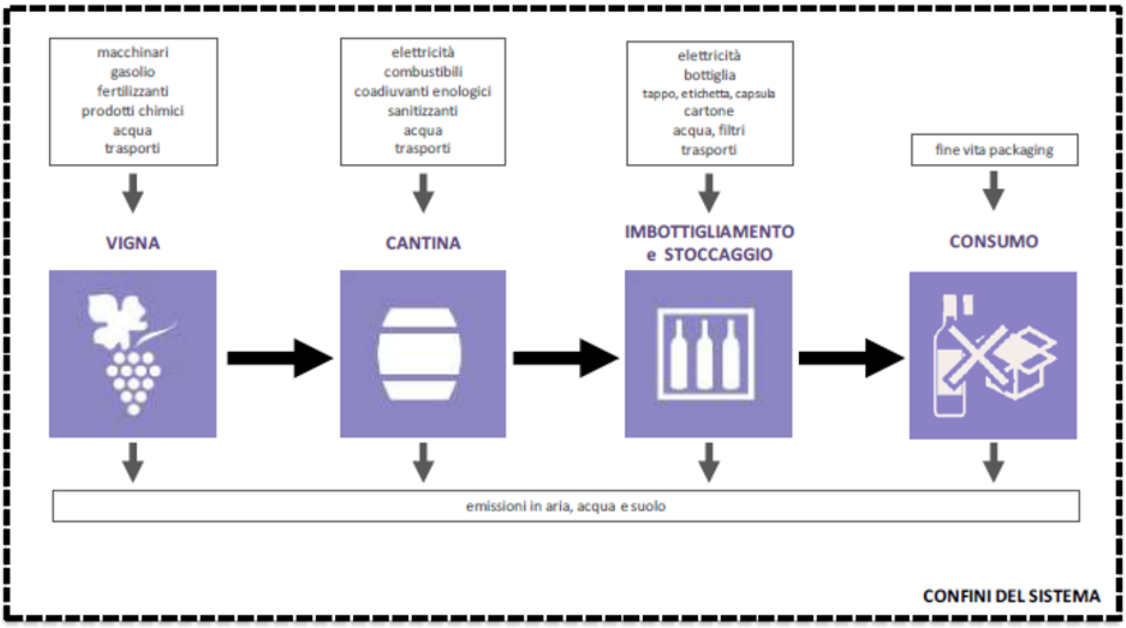


Figure 2.7: Boundaries of the life cycle system of wine bottle production

In the experiment conducted by a Prosecco producer (Perlage, a case study presented in the Appendix of this thesis) on a Valdobbiadene sparkling wine called "Canah," these processes contributed the following percentages (Figure 2.8):

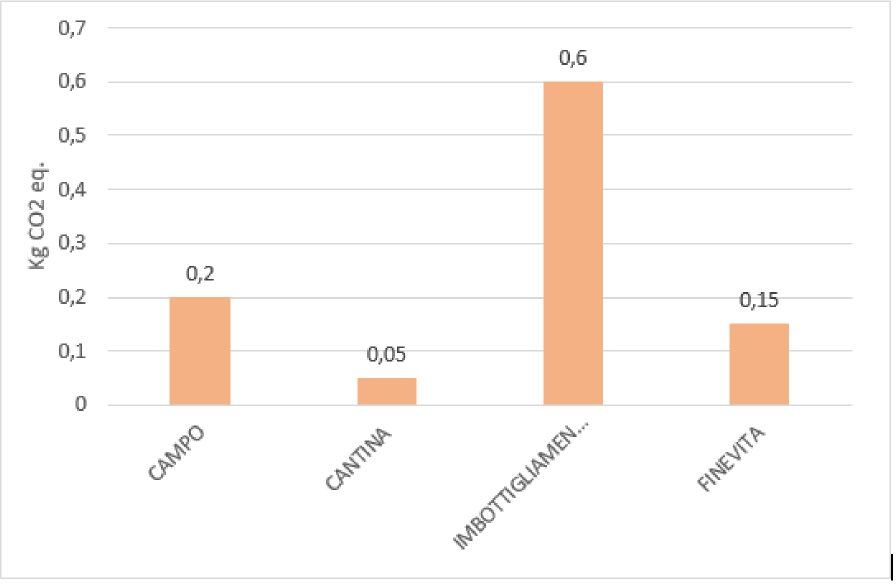


Figure 2.8: Kq di CO2 eq. for a bottle of Prosecco wine (Source: Perlage Winery)

The category indicators considered for the Life Cycle Impact Assessment (LCIA) analysis are Carbon Footprint (CFP) / Global Warming Potential (GWP100).

The carbon footprint, being a "low-hanging fruit" tool as it focuses on a single environmental impact category, can be seen as an opportunity for small and medium-sized enterprises (SMEs) that need to promote a proactive image and meet market interest in eco-labeling initiatives (Arzoumanidis et al., 2014).

In support of this, business accounts are not always clear when it comes to costs related to environmental initiatives. For instance, consider an inter-company environmental collaboration aimed at recovering wasted energy, reusing by-products, or designing greener materials to offset the carbon footprint (Siebrecht, 2020). In the meantime, there may be increased operating costs from collaboration, but the savings related to environmental performance should generate economic performance gains and provide new ways to add value to core business operations, as highlighted by Purba Rao with the term 'Greening the supply chain' (Purba Rao et al., 2002).

In line with the above, the "Greening the supply chain" approach, as emphasized by Purba Rao, can involve inter-company collaborations for the recovery of wasted energy, reuse of by-products, and the design of more ecological materials to offset the carbon footprint.

Specifically, by-products and solid waste generated during winery processes include stems, grape pomace, lees, and grapevines, etc. According to Council Regulation (EC) No. 479/2008 on the common organization of the market in wine, grape pomace and lees must be sent to alcohol distilleries to produce exhausted grape pomace and liquid waste (grape lees) (Devessa-Rey et al., 2011). However, small wine producers usually do not comply with this law and produce wine pomace and lees together with the stems as organic waste.

The main organic waste materials by weight are:

- Stems: the woody structure of the grape cluster, which can constitute between 1.4 and 7% by weight of the fruit (Coelho et al., 2020);
- Grape pomace: the residue from pressing. It is a heterogeneous mass due to agronomic aspects (pruning, climate, ripening) and technological aspects (winemaking process) (Anna Lante, Mara Bortoli, Matricola, n.d.).

Other waste products are generated during the wine production process. Here are some examples:

- Grape skins: During grape pressing to extract the must, the skins are separated from the juice;
- Yeasts and deposits: After the fermentation of the wine, yeast deposits form;
- Washing water: During the cleaning of the equipment and containers used in wine production, washing water is generated, which may contain residues of chemicals and organic substances. This washing water can be treated and reused for non-food purposes, such as irrigation of the land or for cleaning operations within the company;
- Filtration residues: During the wine filtration process to remove unwanted particles, filtration residues are generated, which may include materials such as clays, activated carbon, or filtering materials.

In addition to the waste generated during the wine production process, there is waste resulting from the management of the vines themselves. Here are some examples of such waste products:

- Pruning of vines: During the annual pruning of the vines, excess branches and shoots are removed. These can be considered waste products and can be used for the production of biomass, compost, or can be chipped for recycling as organic material;
- Leaf thinning: During the growth cycle of the vines, leaves can be thinned to improve aeration and grape exposure to sunlight. The removed leaves can be used for composting or can be left on the ground as organic material to improve soil fertility;
- Harvest waste: During grape harvesting, waste such as stems, stalks, and unsuitable grape clusters may be generated. This waste can be directed towards composting or used as animal feed.

Considering the main organic waste materials by weight, such as grape pomace and stems, the potential quantity of by-products in Italy is estimated at 8 million quintals of grape pomace (equivalent to 15% of the vinified grapes) and 2.25 million hectoliters of lees (equivalent to 5% of the wine produced) (Beni et al., 2005).

Among the permitted alternative uses (D.M. 27/11/2008), upcycling in the biopolymers industry is not yet considered. The high carbon content makes grape pomace an ideal substrate for biopolymer preparation, as highlighted by research at the University of Rome Tre, which focuses on recycling and transforming winemaking by-products into bioplastics (Bioplastics From Winemaking By-Products: Environmental and Economic Sustainability, 2019).

Secondly, the aerobic purification of winery effluents generates another solid waste known as winery sludge (Di Laurea & Accademico, 2012).

For example, according to Spanish Law 10/1998, industrial waste must be recycled, recovered, or disposed of to avoid environmental contamination. Many companies choose waste disposal, although economically advantageous alternatives exist for recycling or recovering such waste. For waste disposal, companies must bear the cost of the disposal tax imposed by the authorities.

The latter is a primary point of interest within the scope of this study regarding the management of vineyard waste, specifically grapevines. These are usually present in quantities averaging 1.5 - 2.5 tons per hectar (moisture content 30 - 50%) and can be utilized as a source of renewable energy. This is evidenced by the Veneto Agricoltura agency (Veneto Agricoltura, 2010), which conducted a study evaluating the technical and economic aspects of significant production systems in the province of Treviso. It defined the Directive 2008/98/EC on waste management focusing on recycling and energy conversion.

Emphasizing that, in the perspective of sustainable development, waste disposal is often not taken into account, and only the primary inputs of viticulture are considered, which are:

1) Fertilizers, for providing nutrients

2) Pesticides, for controlling various pests and disease vectors

3) Diesel fuel, for the operation of agricultural machinery

4) Electricity consumption, for the supply of water for irrigation.

Highlighting the relatively low carbon footprint of the latter, Figure 2.9 shows the carbon footprint for inputs on the individual wine bottle of processes in the field. Diesel fuel and fertilizers mainly contribute to the carbon footprint of viticulture, approximately 0.12 and 0.06 kilograms of CO2 per bottle of wine, respectively. Secondly, electricity contributes about half of the fertilizer contribution, and pesticides contribute minimally (0.01 kg CO2 eq. 0.75 L-1 of wine). Thirdly, pesticides and electricity contribute to a lesser extent.

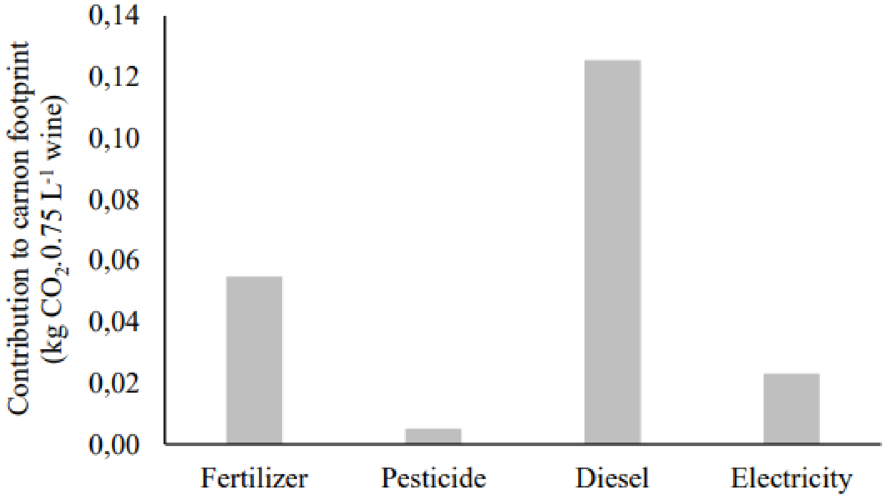


Figure 2.9: Contribution to carbon footprint of a wine bottle per viticulture input

Source: (Arzoumanidis et al., 2014)

Going into detail regarding fertilizers, various by-products are typically destined for spreading on the ground, either without or after composting. In this way, grapevines are used as substitute fertilizers when the circular economy is limited to the agricultural sector and reduce the carbon footprint to as low as 0.06 kg CO2 eq. 0.75 L-1 of wine or are burned in vineyards due to their nitrogen and potassium content.

Considering the components of interest, the literature provides a wealth of information on the characteristics of grapevine cuttings. Firstly, grapevine cuttings have heterogeneous physical and chemical characteristics based on geographic location and the use of pesticides and/or fertilizers. Therefore, an evaluation should be performed in accordance with international and European standards to assess parameters such as moisture content, calorific value, ash content, and elemental composition (including metallic elements like Cu and Zn).

Regarding the reuse of grapevine cuttings for compost production, it is essential to emphasize the importance of composting in viticulture and oenology, which lies in its ability to promote environmental sustainability and improve soil fertility in vineyards. Composting is a sustainable agricultural practice that allows the transformation of by-products from the wine industry and other biomass into an organic fertilizer rich in plant nutrients (Rex Dufour, 2018).

By addressing one of the challenges affecting the wine industry, namely the proper management of by-products generated during wine production, such as grape stems, pomace, and vine pruning waste. In the past, these materials could be considered waste and treated as such, but composting offers a sustainable solution to transform them into valuable resources (Yang et al., 2021).

For example, through the composting process, aerobic decomposition of wine industry by-products results in compost rich in beneficial organic matter for soil (Vinidea Srl, 2021). This compost improves soil structure, enhances water retention capacity, and promotes soil biodiversity. As confirmed by various studies, biochar is known to reduce nutrient leaching (Güereña et al., 2013), decrease the bioavailability of heavy metals (Park et al., 2011), improve soil water retention capacity (Glaser et al., 2002), and plant water availability (Baronti et al., 2014), enhance soil structure (Case et al., 2012), and stimulate soil microbial activity (Kolb et al., 2009; Rutigliano et al., 2014), resulting in increased crop productivity, estimated to be up to 10% across different crops, soils, types of biochar, and application rates (Jeffery et al., 2011).

In an experiment conducted in a vineyard of "Tenuta La Braccesca" (Marchesi Antinori srl, www.antinori.it) near Montepulciano in central Italy, a substantial and significant change in soil physical characteristics was observed. This resulted in a decrease in bulk density and an increase in available water content (Baronti et al., 2014), leading to increased leaf water potential (24-37%) during drought conditions and an increase in grape yield per plant (approximately 10%).

Hence, healthy and fertile soil is essential for successful viticulture as it influences vine growth and grape quality. Composting provides a source of natural and balanced nutrients, improving long-term soil fertility and reducing dependence on chemical fertilizers (Guilbaud et al., 2005).

Specifically, grapevine fertility is determined by factors that may be influenced by biochar, such as nitrogen availability in the previous season (Duchene et al., 2001), as it is known that biochar affects the nitrogen cycle and reduces leaching (Ventura et al., 2013), and temperature regimes near flowering (Ebadi et al., 1996), while changes in soil reflectance (albedo) following biochar application have been shown to affect the distribution of energy flows with a positive increase in soil temperatures (Genesio et al., 2012).

This results in a positive impact on the economic sustainability of the wine industry and contributes to the production of quality wines. Additionally, composting helps mitigate the environmental impact of the wine industry, as the practice contributes to carbon sequestration in the soil (Brenna et al., 2017). Preserving carbon in the soil, rather than releasing it into the atmosphere as carbon dioxide, is an important strategy in the fight against climate change (Brenna et al., 2017).

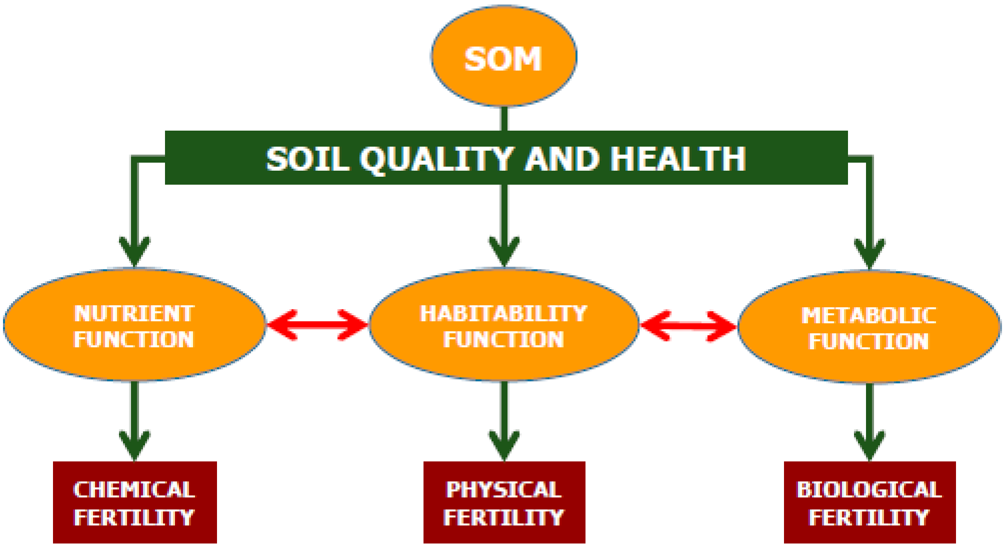


Figure 2.10: Soil Organic Matter (SOM) is a fundamental component of the soil that influences various soil functions, affecting its quality and overall fertility, i.e., the soil's capacity to provide nutrients for producing high-quality crops (Source: Brenna et al., 2017).

The use of compost in viticulture, as in other agricultural/horticultural applications, can yield a wide range of positive effects. However, there is also the potential for harmful effects. Therefore, to ensure safe and effective use of compost in viticulture, it is necessary to adopt appropriate composting practices and quality control measures. This involves carefully managing the composting process to eliminate or reduce harmful pathogens and contaminants while preserving the beneficial properties of the compost.

For this reason and other peculiarities of the companies, here are some of the possible uses of vine shoots, where the choice of the most suitable option will depend on the available resources, technologies, and the specific needs of the company or community involved. It is important to note that biomass uses may vary depending on material availability and local policies. Furthermore, the use of biomass must be sustainable, ensuring proper natural resource management and minimizing negative environmental impacts, in accordance with the provisions of the Kyoto Protocol.

A synthesis of common uses found in the literature is hypothesized:

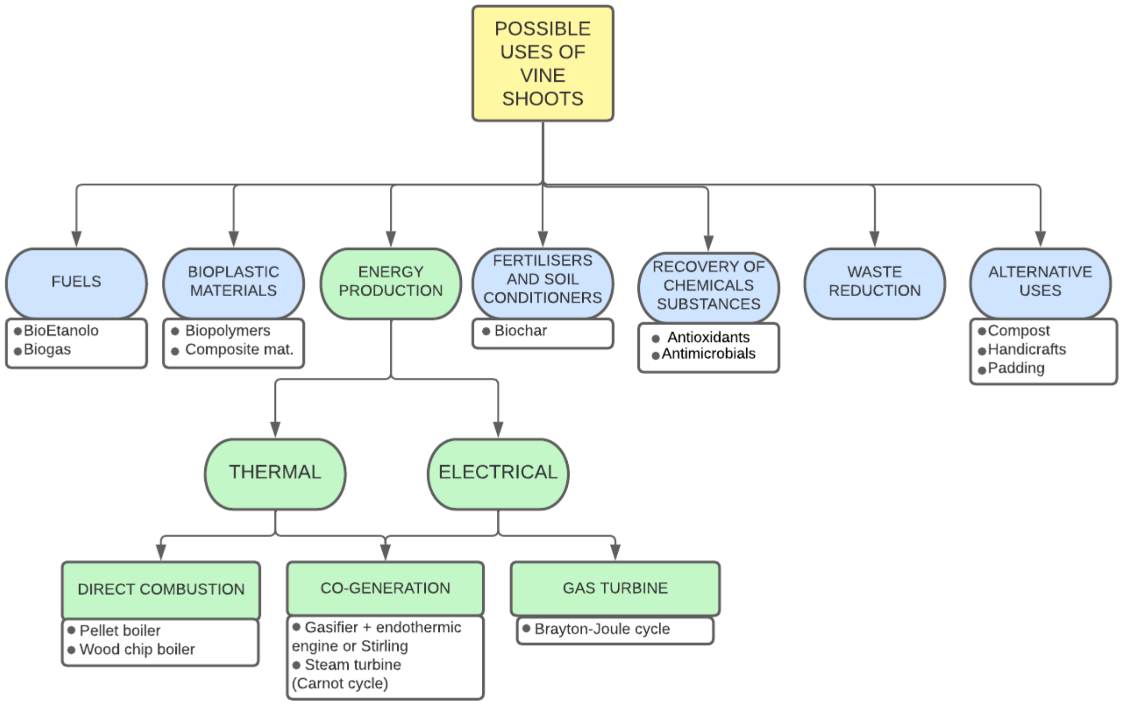


Figure 2.11: Classification of uses of vine shoots (Source: Personal elaboration based on the following articles (Cavalaglio et al., 2007; Pantaleo et al., 2007; Colonna et al., 2010; Corona et al., 2010))

A classification of vine shoots is proposed based on the most common possible uses found in the literature (Figure 2.11). They can be used for energy production, both through direct combustion to generate heat and through biogas production. Biogas can be used to produce electricity and heat, which can be employed for residential or industrial heating. As mentioned above, they can also be converted into other types of fuels such as biofuels (e.g., ethanol and biodiesel for the transportation sector). Several studies highlight an interesting application in the production of bioplastic materials, with the possibility of using them in eco-friendly packaging. This last application is not yet considered in Italy, but there are applications related to extraction processes to recover valuable chemicals, such as antioxidants or antimicrobial compounds. Therefore, the use of vine shoots can contribute to the reduction of organic waste by converting them into useful products.

However, it is important to emphasize that the specific use of vine shoots depends on various factors, including resource availability, local needs, preferences of the agricultural and artisanal industry. For example, there is a use in various local traditions for crafting artifacts such as baskets, weavings, decorative objects, and plant supports due to their flexibility and strength. In the artisanal field, they can also be used as stuffing material for cushions, mattresses, armchairs, and the like, offering a natural and sustainable alternative to synthetic materials. In addition, due to their heat resistance, they can be used in the production of kitchen utensils, such as skewers and barbecue sticks.

However, in the last two decades, the literature has focused more on evaluating the potential for valorizing vine pruning residues for energy production. This practice is primarily part of short supply chains that promote agricultural multifunctionality and territorial redevelopment.

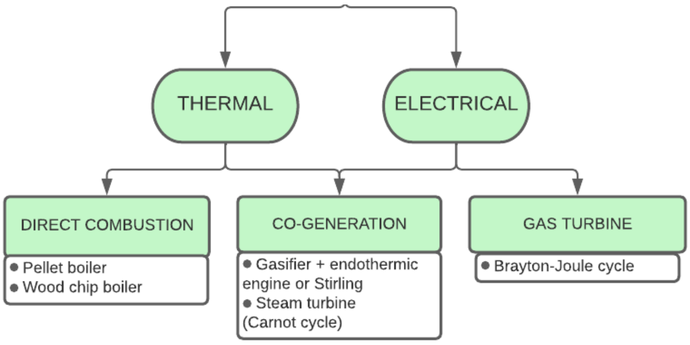


Figure 2.12: Energetic Uses in Terms of Heat and Electricity of Biomass (Source: Personal revision based on the following articles (Cavalaglio et al., 2007; Pantaleo et al., 2007))

Usually, vine prunings are either burned or mulched and buried to return organic matter to the soil (Figure 2.12). However, if there are pests or fungal diseases present, this practice may promote their spread. An alternative is to consider the recovery of vine prunings for energy or biochar production. This might entail an additional cost for the farmer, but it could contribute to the valorization of this biomass and the reduction of waste.

However, there are logistical and organizational challenges to overcome in promoting the use of vine prunings for energy purposes. Despite these difficulties, the potential for energy production justifies the required investment and commitment.

A study conducted in 2022, collecting three grape varieties produced in Veneto (Pinot, Chardonnay, Glera) and comparing three different parts of the vine prunings (internodes, nodes, and pith) (Mencarelli et al., 2022), showed significant differences in energy parameters between the analyzed vine varieties and the different components. The pith exhibited a low calorific value and a high ash content, while the woody components had higher energy values. High Cu and Zn content was found in the woody components, exceeding the reference standards.

Overall, vine prunings were found suitable for potential energy use. However, due to the high ash and Cu content, they are recommended only for industrial purposes in large power plants according to EN ISO 17225-9:2021 standard. (Mencarelli et al., 2022)

This factor represents a technological limitation due to the impossibility of using fixed grate boilers, as the buildup of deposits and slag formation would impair their proper functioning.

Due to its physicochemical characteristics, it can only be used in boilers equipped with the necessary technical adjustments: primary and secondary airflows and grate feeding regulated by a Lambda probe, a mobile grate, and an automatic mechanical ash extraction system. (Puglia et al., 2017).

In a more complex scenario, with substantial by-products to manage, there are examples of Combined Cycles for the production of Electric and Thermal Energy and compost (Biochar), as demonstrated by the case of CAVIRO Distillery for Bioethanol production, Compost, EE - (90% ET required), Wine, and Must (Figure 2.13).

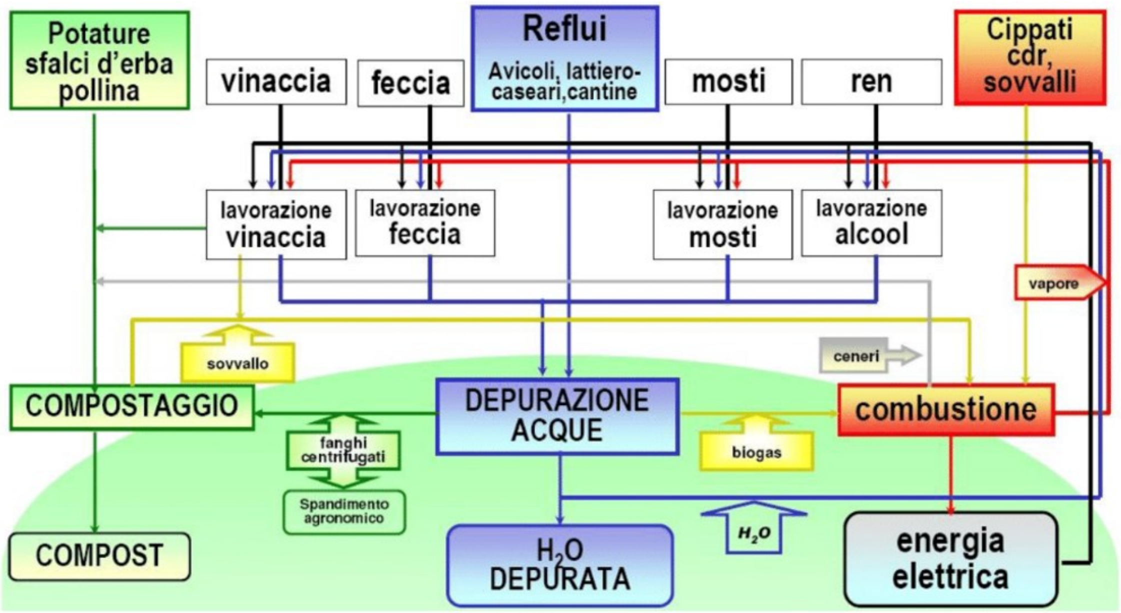


Figure 2.13: Distillery CAVIRO production of Bioethanol and compost (Source: Celotti S., 2009)

On the other hand, in the face of an increasingly challenging resource scarcity, companies are also realizing that the natural market balance can only be achieved through price increases, which are already on the rise due to inflation. In this context, while dealing with rising prices, customers have applied well-known inflation defense strategies: not buying or buying less, changing channels, or switching to another brand. In terms of quantities, purchasing habits change (trading down) as customers gravitate towards products with a lower price index.

In response, companies, unable to lower prices, seek to offer higher-value products by diversifying their offerings (Hussain et al., 2021). The approach embraced by many companies involves innovation toward circular economy business models. This fits into the factors influencing the choice of bottled wine purchase from both 'pull factors' and 'push factors' perspectives, as highlighted by various scientific experiments (Jones, 2012). It also results in an improved brand reputation as an outcome of an efficient Circular Business Model (Figure 2.14, Figure 2.15).

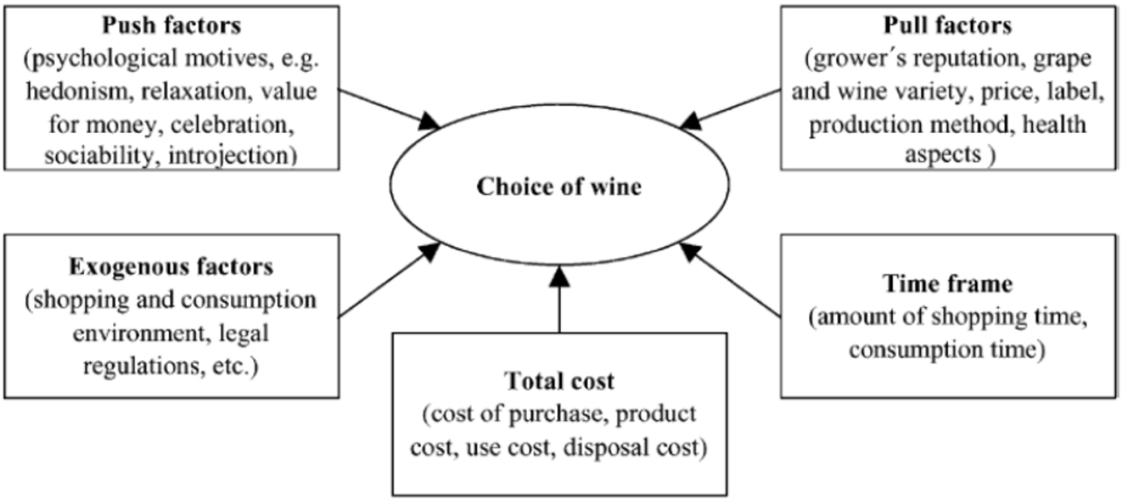


Figure 2.14: Factors influencing the choice of bottled wine purchase

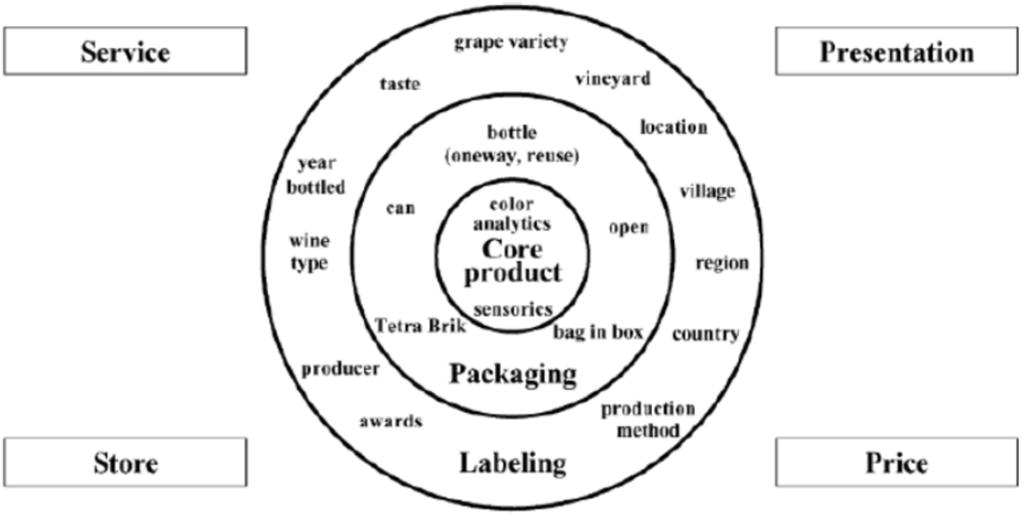


Figure 2.15: Attributes of the product "wine"

The assessment of these attributes and factors, which remained unchanged until a few years ago, is beginning to evolve, especially in the international market. In recent years, numerous studies have highlighted how consumers are showing a growing interest in products considered "sustainable." Sustainability practices are becoming increasingly recognized and adopted throughout the agri-food sector (Jones, 2012). In many cases, sustainability programs (Figure 2.16) are accompanied by certification schemes that make use of "labels" or logos placed on products or, in general, on promotional materials to communicate to the end consumer the producer's commitment to a specific sustainability initiative and/or the achievement of certain performance criteria.

Figure 2.16: Certifications (European and American) regarding sustainable agricultural and related practices.

"Labels can be considered a powerful communication tool since they can convey a range of messages in a simple and immediate way and have subsequent positive effects: in terms of marketing, as they influence the purchasing choices of the end consumer, and more generally, for the promotion of responsible consumption patterns (Heinzle and Wüstenhagen, 2012). It is essential to remember, however, that for wine, "claims," which include all sustainability-related indications and assertions, compete with other product characteristics such as price, brand, region of origin, and grape variety. These are just some of the pieces of information presented on labels that contribute to guiding consumer choices. In general, various studies on consumer perception of sustainable wine have shown, to varying degrees of certainty, that end users are interested in such products and their purchase (Zucca et al., 2009). These studies suggest that consumers would also be willing to pay a premium price, especially in countries with a more recent wine tradition (D'Souza et al., 2006; Forbes et al., 2009). However, it should be noted that a significant portion of the literature has primarily focused on the study of consumer perception of organic wine (Olsen et al., 2011) and eco-labels (Thøgersen, 2000; Barber, 2010). It becomes evident that there is a general lack of research in Italy on how personal values related to environmental issues and expectations regarding sustainability labels influence and define attitudes toward these wines.

Citing a recent study, which demonstrated that the circular economy can serve as a risk reduction strategy. An analysis of 222 European companies active in 14 different sectors showed that as the circularity of the company increases, the risk of default on debts decreases over both a one-year and a five-year horizon. According to the analysis, higher levels of circularity lead to better stock performance in listed companies in Europe. The reasons for these benefits of the circular economy include greater corporate focus on innovation and product and business model diversification, increased resource efficiency, and anticipation of stricter regulations and changes in consumer preferences (Hussain et al., 2021).

In the field of SMEs, there are advanced organic companies and others increasingly inclined to move toward the sustainable circular economy model. This approach does not focus solely on the financial gain of the company but aims to balance this aspect with pro-environmental principles, such as the "three Rs": reduce, reuse, and recycle.

One of the key points of the 3R model is the reuse of by-products. From the analysis of the scientific literature on the energy valorization of grapevine prunings in the wine sector, several key points are highlighted. First, it has emerged that using grapevine prunings for energy production represents an interesting environmental opportunity as it allows the utilization of an agricultural by-product otherwise destined for disposal, and it is documented but with few practical cases in the Italian territory. However, there is limited information on the sustainable advantage of grapevine pruning valorization compared to other alternative techniques to create a continuous cycle of materials and products. This latter aspect is a fundamental approach in the circular economy theory and is shared by various companies in the sector. However, these companies are more inclined if they practice sustainable agriculture, especially in the case of SMEs. In the case of family-run companies, there is no inclination toward these practices, nor is there an "open" vision of possible inter-district collaboration. Therefore, truly active cases are rare and sporadic.

It is appropriate to refer to the "Trade-Off" between "Energy Pruning" and "Soil Pruning." In this regard, it is advisable to introduce two concepts:

- Power-to-Energy (PtE) is a concept related to the conversion of excess renewable energy into other forms of energy or chemical compounds that can be stored and used when needed. This process helps balance energy supply and demand and reduce greenhouse gas emissions.

- Power-to-Soil (PtS), or "power to the soil," refers to the use of renewable energy to improve the soil and promote carbon sequestration. This strategy involves sustainable agricultural practices and targeted soil management to capture and store atmospheric carbon in the soil, contributing to climate change mitigation.

As mentioned earlier, there is no doubt that pruning and their release into the field is to be considered good agronomic practice; however, so far, no explicit comparison has been made with the alternative energy use of pruning. The point, in fact, is whether it is better to focus on the "PtS" option or the alternative one, i.e., "PtE"; in other words, whether the environmental benefits on the fossil fuel substitution front can offset potential environmental disadvantages on the soil degradation front (and the consequent food insecurity). It is interesting to note that this issue has been expressly addressed by conducting a comprehensive Life Cycle Assessment (LCA) of the two contrasting pathways: traditional mulching or pruning versus their energy use.

This result is almost entirely dependent on the overwhelming effect of "fossil displacement" (i.e., replacing fossil fuels with renewables). Therefore, the PtS solution largely depends on the country's energy mix. Observing Figure 2.17, the climate mitigation strategy based on "PtE" revolves around the concept that biogenic carbon flows (derived from biomass) counteract anthropogenic fossil carbon flows. In this way, the linear flow of fossil carbon (from the earth's crust to the atmosphere) should be replaced by a circular flow of biogenic carbon (from the atmosphere to biomass and vice versa) (Pantaleo et al., 2007)."

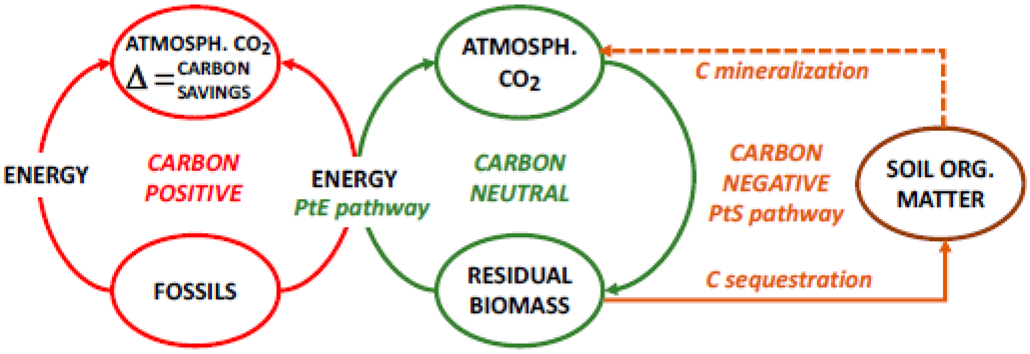


Figure 2.17: Carbon Flows

Considering the opposite but complementary mitigation strategies ("pruning for soil" vs. "pruning for energy"), there are two significant constraints that should be taken into account. These constraints progressively limit the effectiveness of climate mitigation (i.e., the rate of greenhouse gas savings) as they reach a good degree of implementation. This is because:

(a) The efficiency of "fossil displacement" will decrease over time as the average carbon intensity of the energy mix produced (comprising both fossil and renewable sources) is reduced through the replacement of fossil fuels. In fact, the emission factor related to energy use gradually decreases over time due to the increasing share of renewable sources in the energy mix.

(b) The efficiency of carbon sequestration in the soil will decrease over time because the soil organic carbon content approaches a saturation threshold that depends on soil and climate conditions, as well as soil management practices. When these soil carbon saturation conditions occur, only carbon maintenance can be achieved, with no further carbon accumulation. Furthermore, the closer the soil gets to carbon saturation, the less atmospheric CO2 will be sequestered annually.

In light of what has been revealed so far, it should be evident that estimating the trade-off between "pruning for energy" and "pruning for the soil" is not an easy task, as it also depends on the historical trend of renewable energy market penetration and technological maturity, as well as the evolving trend of soil regarding carbon accumulation and fixation.

3. CASE STUDY: BENOTTO

3.1. PROBLEM FRAMING

From the analysis of the scientific literature, it has become evident that energy-related aspects play a strategic role in development policies and environmental initiatives. Currently, the European Union imports more than 50% of its energy resources, and without significant interventions, this dependency could reach 70% by 2030.

The energy deficit situation is particularly critical in our country: Italy currently imports over 82% of its energy needs from abroad, primarily covered by fossil fuels. Additionally, Italy has ratified the Kyoto Protocol, which requires a concrete commitment to reducing greenhouse gas emissions.

The European Union and, consequently, Italy, are increasingly promoting the use of renewable energy sources. Wood represents one of the primary renewable energy resources in Europe, ranking second in Italy after hydroelectric energy. However, the wood-energy sector is developing relatively modestly in our country.

In Italy, the total area dedicated to vineyard cultivation is approximately 700,000 hectares, with the actual production area estimated to be slightly over 670,000 hectares (Agri ISTAT data, 2021). The Veneto region, with approximately 95,000 hectares of vineyards in production, ranks third in terms of vine cultivation area, confirming its significant importance in the national wine industry.

In the regional landscape, the province of Treviso is universally recognized as one of the areas with the highest viticultural vocation, according to authoritative sources, including ISTAT and AVEPA. Recent data, up to September 2021, confirm that the Treviso territory hosts a total area of approximately 41,230 hectares dedicated to vine cultivation, as highlighted in Table 3.1.

Table 3.1: Data concerning the vineyard area assessed in 2021.

I numeri del vino	Superficie (ha/1000)			Uva prodotta (q/1000)			Resa per ettaro (q/ha)			Vino prodotto (hl/1000)		
	2020	2021	Var%	2020	2021	Var%	2020	2021	Var%	2020	2021	Var%
Verona	28.42	28.42	0.0%	3,923	3,945	1%	138	139	1%	3,472	2,959	-15%
Vicenza	7.41	7.23	-2.4%	1,043	978	-6%	141	135	-4%	929	772	-17%
Belluno	0.20	0.21	6.5%	29	28	-4%	147	132	-10%	18	23	25%
Treviso	40.42	41.23	2.0%	6,389	6,568	3%	158	159	1%	4,728	5,174	9%
Venezia	9.87	9.65	-2.3%	1,399	1,488	6%	142	154	9%	1,060	1,190	12%
Padova	7.40	7.04	-4.9%	1,027	996	-3%	139	142	2%	812	793	-2%
Rovigo	0.22	0.20	-11.3%	22	22	-1%	98	110	12%	20	17	-14%
VENETO	**93.95**	**93.98**	**0.0%**	**13,832**	**14,026**	**1%**	**147**	**149**	**1%**	**11,038**	**10,927**	**-1%**

fonte: inumeridelvino.it su dati ISTAT ti ISTAT elvino.it su dati ISTAT ali ISTAT

In the Veneto context, only the province of Verona can boast vineyard extensions comparable to those found in the province of Treviso. With a 42% share of the vineyard area in the region, the province of Treviso holds the leadership in this sector. It is interesting to note that, in recent years, the vineyard area in Treviso has continued to grow steadily, according to ISTAT estimates.

Data provided by AVEPA also confirm the predominance of the province of Treviso within the regional context. Based on the analysis of the vineyard area in the territory up to June 2021, it is revealed that out of a total of 93,980 hectares, a significant 41,230 hectares are located in the province of Treviso, equivalent to approximately 42%. With the addition of new replanting rights reported as of that date (591 hectares), the total vineyard area in the province of Treviso reaches 41,721 hectares, not counting additional replanting rights amounting to 1,864 hectares.

Regarding the information collected in the Veneto Wine Database of 2021, it appears that the province of Treviso actively hosts 47% of the total regional, amounting to 27 thousand companies.

However, despite this success, agricultural companies must face several challenges throughout their supply chain. The activities within the production process of an Agricultural Company include various tasks that can vary in terms of man-hours depending on the size of the land, quantity/quality of vines, and production.

In general, for companies producing re-fermented wines in the Veneto territory, activities can be summarized as follows:

1. Vine Management: This process involves the maintenance of existing vines in the vineyard. It includes activities such as pruning, irrigation management, and control of diseases and pests specific to the vineyard used to produce Prosecco.

2. Soil Management: This process involves the management of the soil around the vines to ensure an optimal environment for plant growth. This may include soil cleaning, weed management, and soil condition assessment.

3. Grape Harvesting: This process focuses on the collection of ripe grapes for the production of Prosecco. Grape harvesting can be done manually or with the help of specific machinery, such as grape harvesters.

4. Grape Crushing: This process involves separating the grape berries from the solid part (stems) through gentle pressing. The goal is to extract the must, which will be used for fermentation.

5. Fermentation: This process involves the fermentation of the must to produce the base wine for Prosecco. Fermentation can take place in temperature-controlled stainless steel containers to preserve the primary aromas of the grapes.

6. Aging: After fermentation, the base wine for Prosecco may undergo an aging period. This can take place in stainless steel tanks or wooden barrels, depending on the desired style of Prosecco.

7. Carbonation for Refermentation: This process involves introducing the base wine into autoclaves, where it undergoes a second fermentation to achieve the characteristic effervescence of Prosecco.

8. Filtration and Stabilization: After the secondary fermentation, the wine undergoes filtration and stabilization processes to remove any impurities and ensure the clarity and stability of Prosecco.

9. Bottling and Packaging: This process involves bottling Prosecco into bottles, applying labels, and sealing with corks or capsules. Subsequently, the bottles are packaged for distribution.

10. Storage and Preservation: This process involves storing Prosecco bottles in the warehouse, taking into account the necessary temperature and humidity conditions to preserve its quality.

11. Sales and Distribution: This process involves marketing and distributing Prosecco to customers.

To improve understanding of the topic, from the perspective of Visual Management, a general process mapping has been included as shown in Figure 3.1.

Figure 3.1: Mapping of activities in an agricultural company.

The mapping highlights the points in the process where by-products are generated, underscoring that the sector must face additional challenges, such as the issue of disposing of these "waste products" (Mencarelli et al., 2022). In summary, various by-products can be internally valorized or directed towards cross-market opportunities (Puglia et al., 2017; Pantaleo et al., 2007; Colonna et al., 2010; Corona et al., 2010).

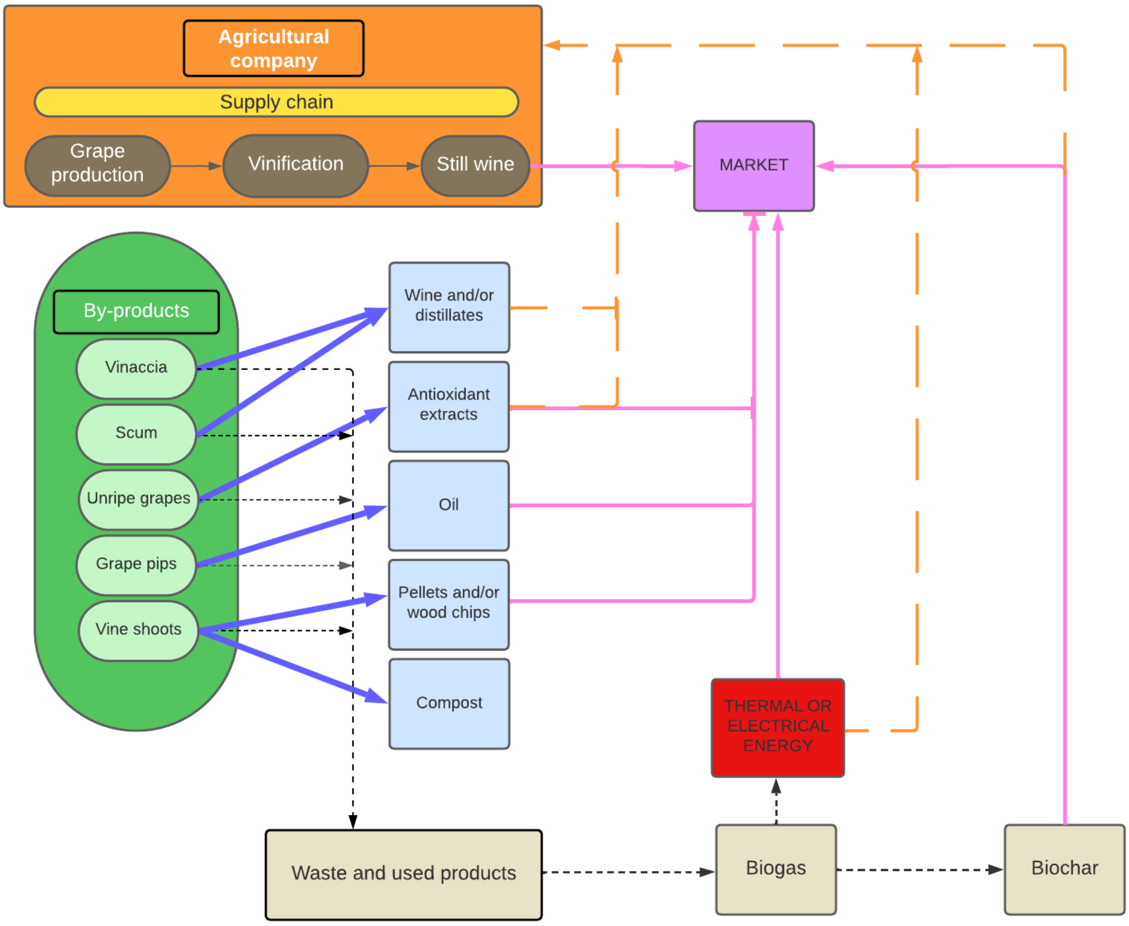


Figure 3.2: By-products derived along the agribusiness supply chain.

As confirmed by the literature, the sustainable management of by-products in the wine industry has become of increasing interest. Companies are exploring various options to valorize these materials (Figure 3.2), such as using them for compost production or biomass for energy purposes. This approach helps reduce the costs associated with by-product disposal and has a positive impact on the environment.

However, currently, pruning residues do not constitute a source of income for the companies involved; on the contrary, they often represent an additional problem and increase production costs. Pruning residue management has mainly focused on two solutions:

1) Shredding in the field along the rows of vines, followed by burying the residues in the soil.
2) Burning the residues.

The practice of shredding and burying can be advantageous in healthy vineyards where the pruned branches do not pose a source of infections or disease spread but can instead contribute nutrients and organic matter to the soil. However, this practice can have a negative impact on phytosanitary conditions in unhealthy vineyards affected by various diseases such as esca, root rot, or Eutypa dieback.

In this context, burying the vine shoots should be avoided, as the pathogen finds a favorable environment in the soil to survive during the winter and reinfect the buds in the following spring, compromising phytosanitary control.

In many cases, the vine shoots are collected using a tractor-mounted rake and brought to the field's peripheral areas to be subsequently burned. However, this solution is often prohibited in many regions due to the negative environmental consequences related to emissions caused by this agricultural practice, as well as fire safety precautions.

The act of burning the vine shoots outdoors is often prohibited by numerous municipal administrations, although non-compliance with such regulations is sometimes observed. In the context of the Regional Plan for the Protection and Restoration of the Atmosphere, approved in 2004 by the Veneto Region, a Technical Zonal Table was established in the province of Treviso, dividing the territory into five homogeneous zones based on the indications provided by ARPAV. Various actions and measures have been taken to limit the release of pollutants into the atmosphere to preserve its quality.

Among these measures, it is important to mention the "ban on open-air burning for anyone, especially in agriculture and construction, with the exception of pruning vine shoots when required for phytosanitary purposes by regional regulation." In this context, reference can be made to the orders issued by the Municipality of Conegliano on December 29, 2009, and by the Municipality of Oderzo on December 24, 2009.

Since both burying and burning the vine shoots have environmental and phytosanitary disadvantages, an alternative for vine shoot disposal must be found. One potential solution could be their recovery and valorization for energy purposes.

According to Legislative Decree No. 22/97 (Ronchi Decree), pruning residues, when they need to be disposed of, fall into the category of waste. However, if they are destined for energy use, as provided for in Legislative Decree No. 152/06 (formerly DPCM March 8, 2002), they can be considered fuels in every respect.

The main objective of this study is to evaluate the circular approach of an energy recovery method for woody residues from vine pruning, with a focus on the Prosecco area. The aim is to transform the current problem represented by these residues into an income opportunity for agricultural companies. This can be achieved through the implementation of local short supply chains, which would bring benefits to both the companies and the surrounding rural area.

During the study, a preliminary analysis of the current situation in the province of Treviso was carried out to estimate the availability of biomass resulting from the recovery of vine pruning vine shoots. This analysis includes data on cultivated areas, potential production, and a comprehensive analysis.

Based on this initial quantitative assessment, an operational reality in the province of Treviso that produces wood chips from vine prunings was examined. The technologies used for the recovery of pruning materials were reviewed, evaluating the costs of collection, transport, and biomass transformation into the finished product (wood chips).

Experiments conducted in the Treviso area by the Agricultural Cooperative Society Livenza - COAL in Motta di Livenza showed that about 1.2 tons of pruning vine shoots with a moisture content of 10% can be obtained per hectare of vineyard per year, suitable for energy use.

Based on this data, it is possible to estimate the annual amount of biomass obtainable through pruning practices in the vineyards located in the province of Treviso. Starting from the AVEPA data for 2021, which reports 41,230 hectares of Prosecco currently in production in Veneto and considering that about 20% of this area may not be technically and economically suitable for harvesting, the availability of fresh vine shoots is estimated to be approximately 65,000 tons per year (40% moisture). Using the COAL experiments as a reference, which recorded an average production of 1.2 tons per hectare per year, the actual availability (excluding the 20%) of vine shoots in terms of dry matter would be around 42,000 tons per year.

Calculating the lower heating value (LHV) of vine chipboard and considering its use in modern combustion plants, it is possible to roughly estimate the energy that can be generated from this available raw material. Literature indicates an average LHV for vine chips between 3.3 and 3.4 kWh/kg (with 35% moisture). However, this calorific value depends on the moisture content: as further experiments show, the LHV can be around 4.2 kWh/kg (with 15% moisture) (Pivetta D. et al., 2020) or can reach 4.6 kWh/kg (with 10% moisture)

3.2. AGRICOLTURAL COMPANY: BENOTTO

The agricultural company Luigino Benotto under consideration in this case study is located in Veneto, or more precisely, in Valdobbiadene, the cradle of Prosecco DOCG (Figure 3.3). Like most businesses in the area, it is family-run, with approximately 15 employees, and an increase in temporary staff during the harvest season (September - October).

Dati Basici Az. Agr Benotto Luigino	
Coordinate	45° 54' 5" Nord, 11° 59' 43" E
Altitudine	253 m.s.l.m.

BENOTTO LUIGINO
SPUMANTI
Fondata nel 1873

Figure 3.3: Characterization of the production area of Prosecco DOC and DOCG, and the location of the Agricultural Company.

The Benotto Family personally and meticulously oversees the entire production process of their wines, starting from the cultivation of their estates (and the selection of each new estate acquired), proceeding through all stages of harvesting, winemaking, bottling, and storage, right up to the direct delivery to the end customer. All of this is achieved using exclusively their own resources, structures, and facilities (with the exception of the Classic Method, where winemaking and bottling are carried out by a selected and trusted partner, nevertheless, under their direct supervision).

Figure 3.4: Top View of the Central Headquarters

Figure 3.5: Top View of the Waste-to-Energy Plant Site

The agricultural company owns estates in various locations within the Prosecco DOCG territory, including S. Pietro di Barbozza, S. Vito di Valdobbiadene, Isola di Sant'Erasmo, Asolo, and the Cartizze area (Figure 3.4, Figure 3.5). As a result, the range of wines that the company markets in its own markets is highly diverse (Figure 3.6).

Figure 3.6: Some examples of the Wine Line (starting from the left: Nobildonna (S. Erasmo), Prosecco DOCG Colli Asolani, and Tranquillo.

The agricultural company Luigino Benotto, considered in this case study, is located in the Veneto region, specifically in Valdobbiadene, the heart of Prosecco DOCG. Like most businesses in the area, it is family-run, with around 15 employees, and experiences an increase in staff during the grape harvesting period (September to October).

The agricultural company owns estates in various areas within the Prosecco DOCG territory, including S. Pietro di Barbozza, S. Vito di Valdobbiadene, Isola di Sant'Erasmo (DOC), Asolo, and the Cartizze zone. Therefore, the range of wines it offers is diverse.

In this discussion, a standard reference of one hectare of vineyard in the DOCG area (Figure 3.7) will be used. A cost average will be considered across different plots to define an estimated value, as the collected data is not exhaustive to establish a specific vineyard as a reference.

Figure 3.7: Prosecco vineyards in the Valdobbiadene area (TV)

AZIENDA BENOTTO: PROSPETTO "AS-IS"

The activities carried out within the Benotto Agricultural Company, from the vineyard to the bottle, were mapped "as-is" and analyzed in detail until a few months ago (Figure 3.8):

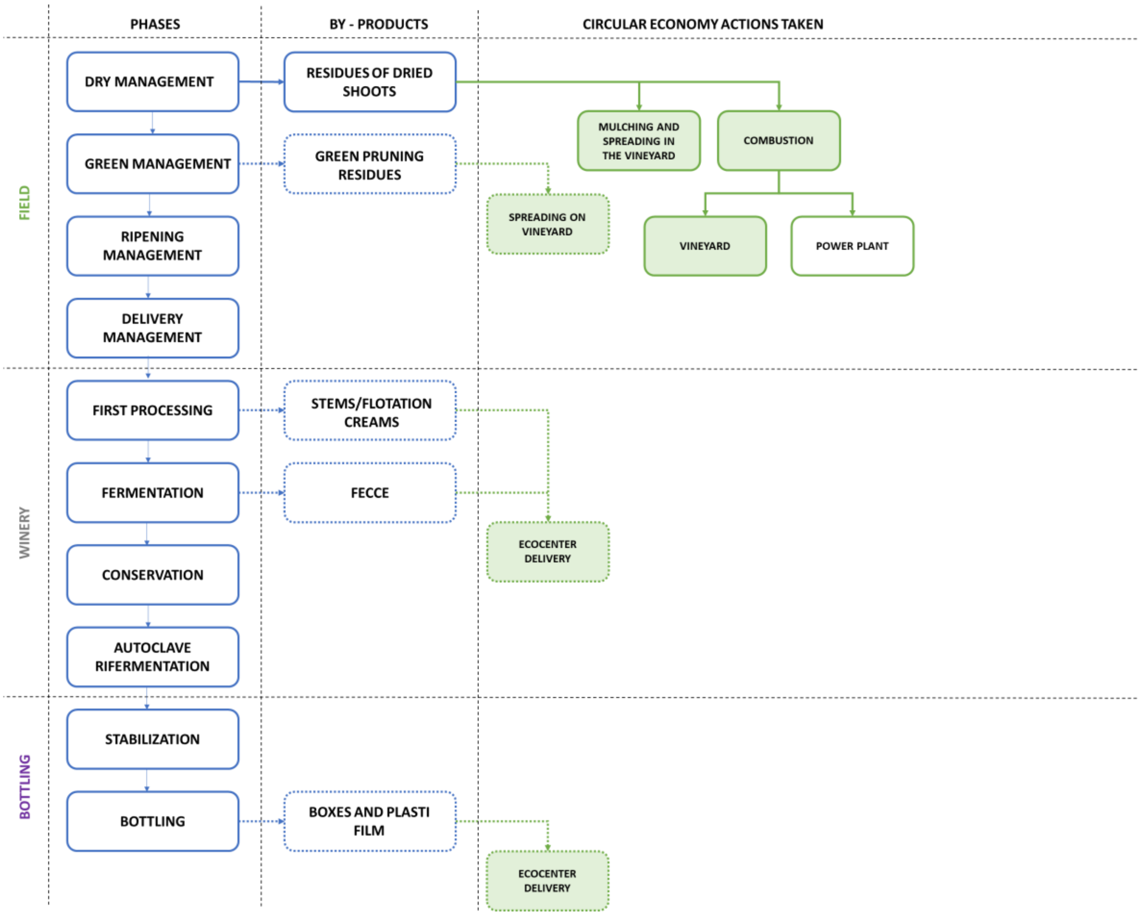


Figure 3.8: Mapping of the process carried out by the Agricultural Company and initial actions towards the Circular Economy before the introduction of the waste-to-energy plant

As can be noted, before embarking on its "to-be" path of revaluing vineyard by-products, the company managed waste as follows:

- The waste from dried vine shoots and vine shoots was managed differently: part of it was shredded and spread in the vineyard, while another part was burned in open air.
- The waste from green pruning was managed by spreading it in the vineyard.
- All other company by-products were disposed of in landfills.

Considering what emerged from the mapping and scientific literature, some considerations can be immediately drawn, and certain critical points highlighted. Firstly, the management of pruning waste by spreading it in the vineyard can pose a significant issue in terms of phytopathology. Managing both dry and green waste in the vineyard is a particularly critical step in terms of soil health and biodiversity preservation. Therefore, it is crucial, before spreading, to be able to sanitize the vine shoots by passing them through an aerobic or anaerobic composting process. In this case, the company did not follow this practice, assuming a substantial risk.

Another critical aspect is the open-air burning of vine shoots, which is not a virtuous practice for both environmental reasons and because it does not allow for the recovery of the generated heat for internal use within the company.Finally, regarding disposal in landfills, this practice is advisable only if there are no other valid alternatives for revaluing by-products. The literature suggests numerous circular economy actions, but the company had not yet considered them. A closely related consideration is linked to the production cycle. The production of sparkling wines requires significantly more thermal management (heating and cooling) compared to still wines. Naturally, the heating and cooling in the company must be produced using different energy vectors, such as electricity from the domestic grid. In the case of sparkling wines, an important energy factor is the heat required in the heating tunnel during the bottling process. This heat could easily be produced by biomass combustion, which, as revealed in the mapping, was available in the company, albeit intermittently. In the "as-is" configuration of the Benotto company, the heat required for the heating tunnel and all other company utilities (offices, warehouses, etc.) was produced using various energy sources. One of these was a manually loaded wood boiler, model CSL 130-950 (Figure 3.9, Figure 3.10, Figure 3.11), a three-pass smoke boiler powered by wood purchased from external sources.

Figure 3.9: Biomass Boiler D'Alessandro CSL 130-950

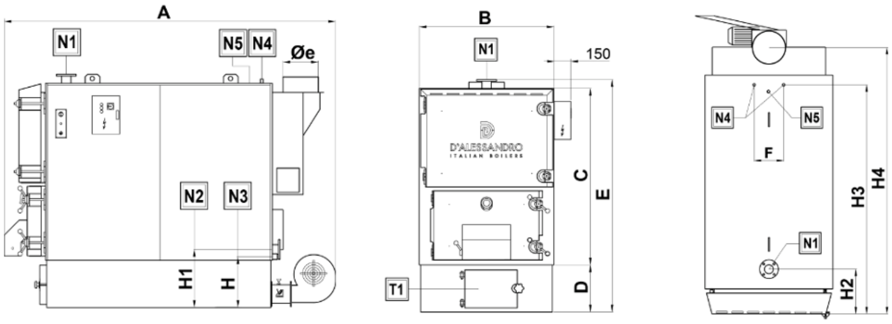


Figure 3.10: Side View, Front View, and Plan View

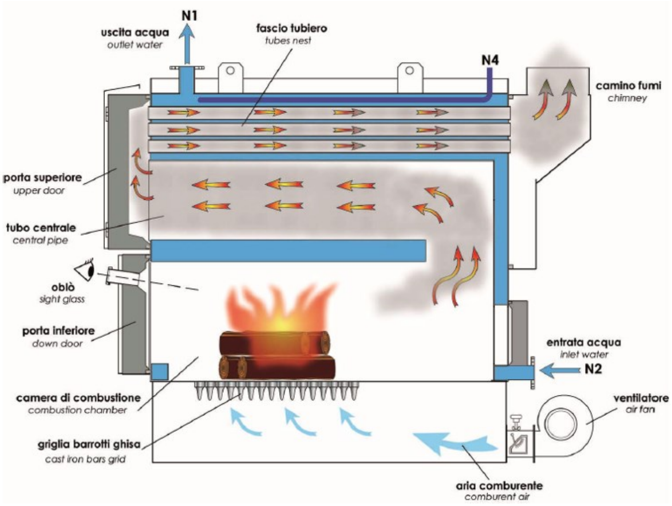
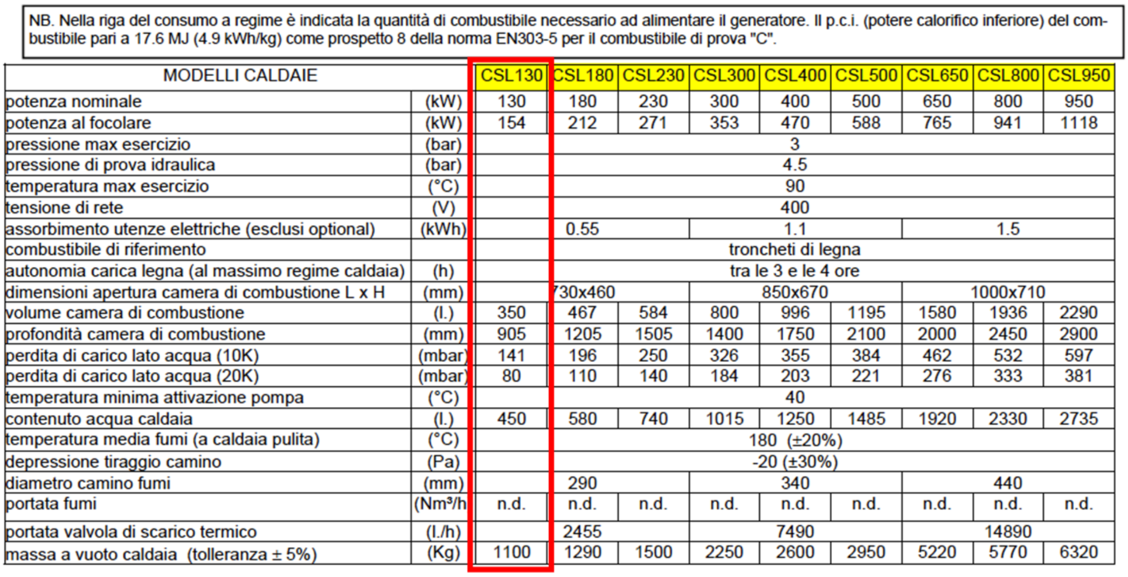


Figure 3.11: Boiler Operating Diagram

As evident from Figure 3.11, in this type of boiler, the fuel in the combustion chamber is burned with the introduction of combustion air supplied by the blower located at the rear of the base. The heat generated in the combustion chamber is transferred to the water-filled spaces through the steel walls of the generator. The hot gases, rising from the combustion chamber, pass through the central tube and, via the upper door cavity, traverse the tube bundle until they are expelled in the rear smoke connection, completing the three smoke passes that characterize this type of heat generator. Optimal combustion control is achieved by making the necessary adjustments to primary and secondary air and fuel input, while combustion quality can be visually inspected or monitored using specialized flue gas analyzers. However, the CSL130 boiler model in question is considered obsolete when compared to modern boilers, and it had the limitation of manual loading and limited autonomy (approximately 3-4 hours), as indicated in the technical specifications below (Figure 3.12):



NB. Nella riga del consumo a regime è indicata la quantità di combustibile necessario ad alimentare il generatore. Il p.c.i. (potere calorifico inferiore) del combustibile pari a 17.6 MJ (4.9 kWh/kg) come prospetto 8 della norma EN303-5 per il combustibile di prova "C".

MODELLI CALDAIE		CSL130	CSL180	CSL230	CSL300	CSL400	CSL500	CSL650	CSL800	CSL950
potenza nominale	(kW)	130	180	230	300	400	500	650	800	950
potenza al focolare	(kW)	154	212	271	353	470	588	765	941	1118
pressione max esercizio	(bar)		3							
pressione di prova idraulica	(bar)		4.5							
temperatura max esercizio	(°C)		90							
tensione di rete	(V)		400							
assorbimento utenze elettriche (esclusi optional)	(kWh)		0.55		1.1			1.5		
combustibile di riferimento			troncheti di legna							
autonomia carica legna (al massimo regime caldaia)	(h)		tra le 3 e le 4 ore							
dimensioni apertura camera di combustione L x H	(mm)		730x460		850x670			1000x710		
volume camera di combustione	(l.)	350	467	584	800	996	1195	1580	1936	2290
profondità camera di combustione	(mm)	905	1205	1505	1400	1750	2100	2000	2450	2900
perdita di carico lato acqua (10K)	(mbar)	141	196	250	326	355	384	462	532	597
perdita di carico lato acqua (20K)	(mbar)	80	110	140	184	203	221	276	333	381
temperatura minima attivazione pompa	(°C)		40							
contenuto acqua caldaia	(l.)	450	580	740	1015	1250	1485	1920	2330	2735
temperatura media fumi (a caldaia pulita)	(°C)		180 (±20%)							
depressione tiraggio camino	(Pa)		-20 (±30%)							
diametro camino fumi	(mm)		290		340			440		
portata fumi	(Nm³/h	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
portata valvola di scarico termico	(l./h)		2455		7490			14890		
massa a vuoto caldaia (tolleranza ± 5%)	(Kg)	1100	1290	1500	2250	2600	2950	5220	5770	6320

Figure 3.12: Technical characteristic CSL 130-950

AZIENDA BENOTTO: PROSPETTO “TO-BE”

As a result of the identified challenges, the company has opted to shift its strategy by introducing technologies aimed at embracing modern circular economy principles. Therefore, as its initial pilot project, it decided to focus on the recovery of vine prunings for energy production using a biomass boiler, as demonstrated in the "to-be" mapping in Figure 3.13:

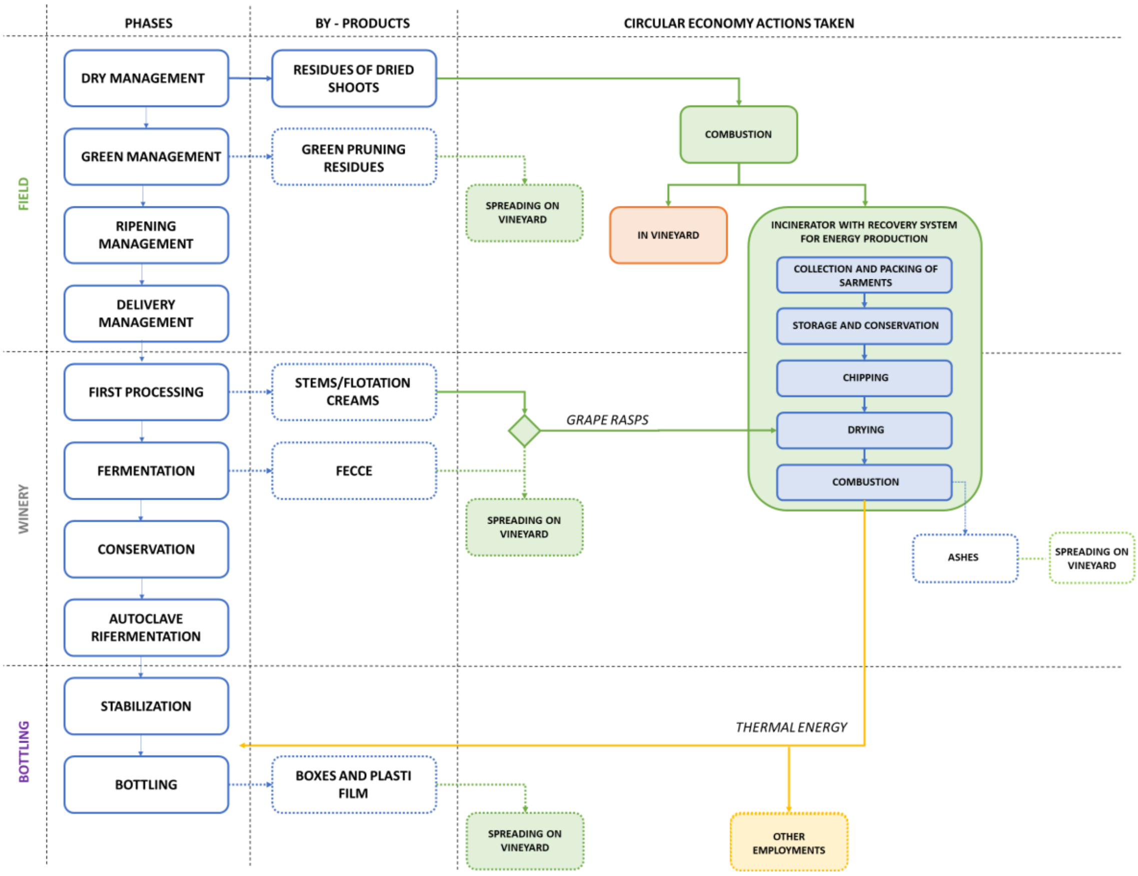


Figure 3.13: Mapping of the process carried out by the Agricultural Company and initial actions aimed at Circular Economy after the introduction of the waste-to-energy plant

In light of what has been discussed so far, it becomes evident that the decision of the Benotto company to integrate a circular economy action within the production process to recover heat from vine prunings is not a random choice but very well aligned with the specific work cycle's requirements. Figure 3.13 highlights how the system introduced in the company allows for the recovery of the heat generated by burning vine prunings to supply the hot utilities in the cellar, including the heating tunnel in the bottling line. From an energy perspective, the company has also chosen to proceed with the installation of some photovoltaic panels to provide flexibility to the biomass system.

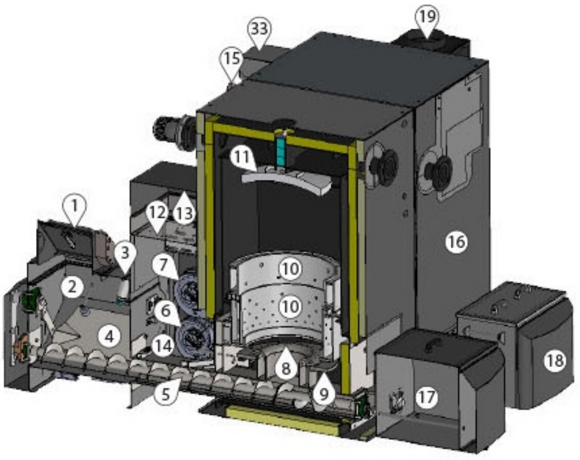
The analysis of the "to-be" mapping also demonstrates how the implementation of a circular economy project related to a single phase of the production process can actually bring several benefits to the entire cycle. In the combustion system, not only can the dried components resulting from vineyard shredding be introduced, but also all components of the cellar's production process (destemming, etc.), which, after proper drying, can contribute positively to heat generation.

Following the improvements introduced in the "to-be" configuration, the Benotto Company is now capable of generating energy through:

- Solar thermal panels, thanks to the National Recovery and Resilience Plan (PNRR) - Mission 2 Component 1 (M2C1) - Investment 2.2 - Agrisolar Park, funded by the European Union with a grant of 75,000 euros.
- Thermal recovery in engines, resulting from the Joule effect.
- SMART 400 Boiler.

Figure 3.14: Front view of the automatic boiler (SMART 400)

(Fonte: https://www.smartheating.cz/it/smart-400-kw/)



1. Valvola antincendio
2. Sensore livello combustibile
3. Contenitore intermedio combustibile
4. Meccanismo movimento combustibile
5. Coclea di dosaggio
6. Ventilatore aria primario
7. Ventilatori aria secondari
8. Anello combustione primario
9. Bruciatore con piatto vibrante
10. Anello inferiore e superiore bruciatore in materiale fibroceramico
11. Cappello riflettente fibroceramico
12. Unità controllo Siemens
13. Coperchio unità di controllo dotato di display
14. Accessori
    - elemento d'accensione
    - mecanismo di estinzione in emergenza
    - sensori temperatura di sicurezza
15. Servoazionamento sportello scambiatori
16. Scambiatori di calore con turbulatori
17. Cassetta ceneri camera di combustione

Figure 3.15: Section view of the automatic boiler (SMART 400)

(Fonte: https://www.smartheating.cz/it/smart-400-kw/)

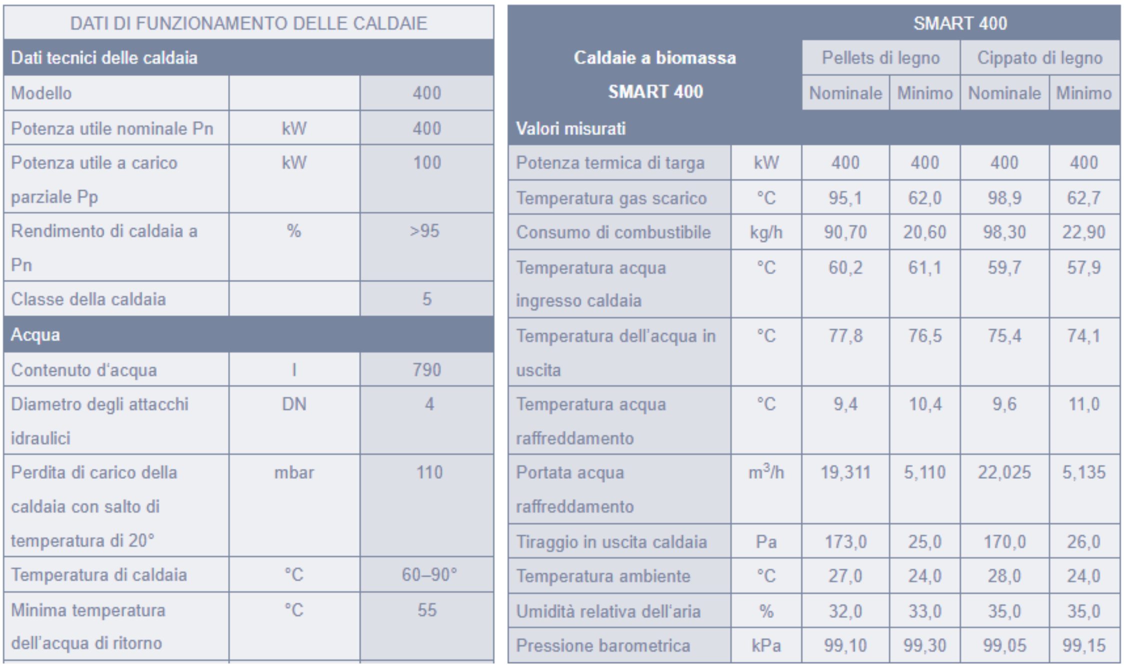
A	B	C	D	E	F	G	H	CH
2940	2320	2720	1060	1995	1560	1790	750	655

PESPESI OS		
Camera di combustione 300–500 kW	1 550 kg	Peso total
Scambiatore 400 kW	1 700 kg	3 250 kg

Figure 3.16: Dimension and main characteristic

(Fonte: https://www.smartheating.cz/it/smart-400-kw/)

Table 3.2: Technical characteristic of the boiler SMART 400 (Fonte: https://www.smartheating.cz/it/smart-400-kw/)



DATI DI FUNZIONAMENTO DELLE CALDAIE		
Dati tecnici delle caldaia		
Modello		400
Potenza utile nominale Pn	kW	400
Potenza utile a carico parziale Pp	kW	100
Rendimento di caldaia a Pn	%	>95
Classe della caldaia		5
Acqua		
Contenuto d'acqua	l	790
Diametro degli attacchi idraulici	DN	4
Perdita di carico della caldaia con salto di temperatura di 20°	mbar	110
Temperatura di caldaia	°C	60–90°
Minima temperatura dell'acqua di ritorno	°C	55

Caldaie a biomassa SMART 400		SMART 400			
		Pellets di legno		Cippato di legno	
		Nominale	Minimo	Nominale	Minimo
Valori misurati					
Potenza termica di targa	kW	400	400	400	400
Temperatura gas scarico	°C	95,1	62,0	98,9	62,7
Consumo di combustibile	kg/h	90,70	20,60	98,30	22,90
Temperatura acqua ingresso caldaia	°C	60,2	61,1	59,7	57,9
Temperatura dell'acqua in uscita	°C	77,8	76,5	75,4	74,1
Temperatura acqua raffreddamento	°C	9,4	10,4	9,6	11,0
Portata acqua raffreddamento	m^3/h	19,311	5,110	22,025	5,135
Tiraggio in uscita caldaia	Pa	173,0	25,0	170,0	26,0
Temperatura ambiente	°C	27,0	24,0	28,0	24,0
Umidità relativa dell'aria	%	32,0	33,0	35,0	35,0
Pressione barometrica	kPa	99,10	99,30	99,05	99,15

However, the main characteristics of the energy conversion system and the chosen distribution network are as follows:

- Chip storage silos with a useful volume of approximately 80 m3, capable of ensuring the boiler's autonomy for at least 20 days under the most demanding load conditions.
- Chip transport system from the silos to the combustion chamber consisting of mobile rakes at the bottom of the silos and loading screws to the boiler.
- Mobile grate boiler technology, which allows greater flexibility in terms of material moisture and particle size, factors that, as already observed, can vary considerably depending on the season or the duration of the chipping cycle.
- Plant size of 400 kW (useful), resulting from a compromise between the company's energy needs and the amount of energy obtainable from the vine prunings.
- Thermal transfer fluid used: diathermic oil up to 300°C, which will enable the production of the steam required for the bottle sterilization process.

- Use of diathermic oil-hot water and diathermic oil-steam heat exchangers for the distribution of energy to the users.

It should be emphasized that the need to reduce the cost of thermal energy for heating the bottles before labeling and at the same time address the problem of neighboring producers who, by law, were denied the possibility of burning the prunings "in the open air," has allowed the Benotto company not only to make an investment for its own company but also for the neighboring area. The legislation on PM10 emissions was decreed by the national land plan (PAN) approved by DM of 22/01/2014, which declared that it is not possible to burn in the field, where in Valdobbiadene, this practice is sanctioned. In this case, the vine pruning residues usually pose a problem and, at the same time, incur a cost for their disposal. Currently, the Italian wood chip market exhibits the typical characteristics of emerging markets and is characterized by significant complexity and territorial diversity. In some regions and areas, intense competition can be observed between the use of wood chips for energy purposes and other destinations, such as the panel industry or pulp production. The production of wood chips shows very variable and uneven costs. On the one hand, there are situations where wood chips are obtained from difficult-to-access forests, resulting in high costs. On the other hand, there is the use of waste material directed to power plants, with lower costs. The landscape of end users is highly diversified, with different spending propensities among the various categories. Currently, there is no standardized model appropriate for the buying and selling of fuel based on its energy content. Regarding wood chips, there are primarily three market sectors:

1. Large power plants;
2. District heating systems, some of which are combined with cogeneration;
3. Small-scale district heating networks and domestic boilers.

Other cases can be those of retail sales, as shown below (Figure 3.17) as an example:

Figure 3.17: Alternative markets of Vine Shoots (es. BBQ)

Therefore, the possibilities for the valorization of these byproducts are diverse and sometimes minimally applied, if not solely for experimentation. To achieve the objectives set by the company, such as the transition to a cleaner energy source, the activities are planned throughout the year, involving various stakeholders.

In detail, in the implementation of its vineyard byproduct optimization strategy, Benotto has meticulously planned the process. During the spring, field surveys were conducted to assess the vineyard characteristics. It was observed that the vineyards consist primarily of grassy rows, with row spacing ranging from a minimum of 2.40 meters to a maximum of 3.1 meters (except in the Cartizze area). The vine training systems primarily follow a trellis shape, with the Guyot type being predominant (see Photo 1). The company estimated that one hectare of Glera variety vineyard produces approximately 22-25 quintals of moist vine prunings.

For the collection and packaging of the vine prunings, collaboration was established with a specialized agricultural services company. For this purpose, a conventional hay baler was used, capable of producing bales with dimensions of 1.5 m * 1.2 m, wrapped with containment net. The operation was carried out using an agricultural tractor, to which the baler was attached via the three-point hitch (Figure 3.18, Figure 3.19).

To ensure optimal results, the collection of the vine prunings was organized by creating "lanes" between the rows.

Figure 3.18: A) Rows of vine prunings between the rows. B) Baler in operation during the collection phase

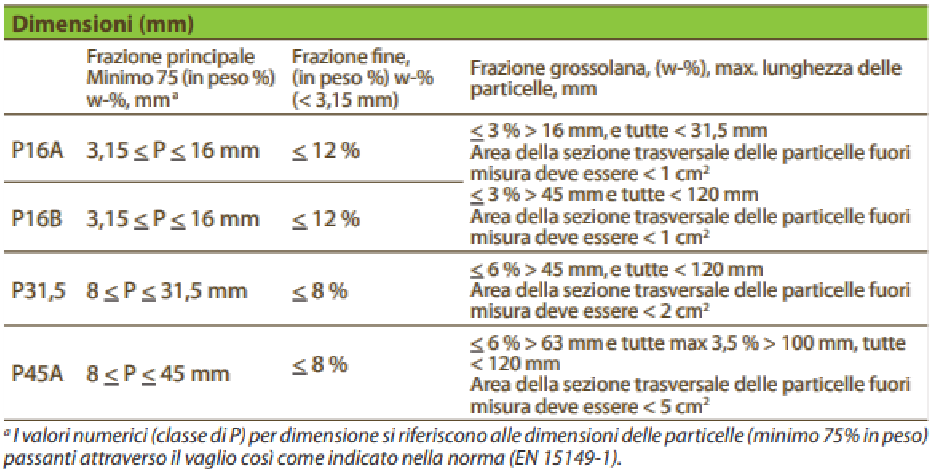
Figure 3.19: C) Baler in operation during the release of the bale wrap. D) Bale wrap of vine prunings.

This type of physical treatment reduces the size of the biomass depending on its intended use, shredding trunks and branches into smaller and more manageable pieces. This initial size reduction increases the bulk density of the biomass, making it easier to transport and store.

For the shredding process, crushers employing hammers are used to break down the incoming material into smaller dimensions.

Table 3.3 classifies wood chips according to the EN - ISO 17225-4 standard based on their sizes.

Table 3.3: Characterization of wood chip particle size (EN 14961-4: 2010)



Dimensioni (mm)			
	Frazione principale Minimo 75 (in peso %) w-%, mm[a]	Frazione fine, (in peso %) w-% ($< 3,15$ mm)	Frazione grossolana, (w-%), max. lunghezza delle particelle, mm
P16A	$3,15 \leq P \leq 16$ mm	≤ 12 %	≤ 3 % > 16 mm, e tutte $< 31,5$ mm Area della sezione trasversale delle particelle fuori misura deve essere < 1 cm^2
P16B	$3,15 \leq P \leq 16$ mm	≤ 12 %	≤ 3 % > 45 mm e tutte < 120 mm Area della sezione trasversale delle particelle fuori misura deve essere < 1 cm^2
P31,5	$8 \leq P \leq 31,5$ mm	≤ 8 %	≤ 6 % > 45 mm, e tutte < 120 mm Area della sezione trasversale delle particelle fuori misura deve essere < 2 cm^2
P45A	$8 \leq P \leq 45$ mm	≤ 8 %	≤ 6 % > 63 mm e tutte max 3,5 % > 100 mm, tutte < 120 mm Area della sezione trasversale delle particelle fuori misura deve essere < 5 cm^2

[a] *I valori numerici (classe di P) per dimensione si riferiscono alle dimensioni delle particelle (minimo 75% in peso) passanti attraverso il vaglio così come indicato nella norma (EN 15149-1).*

TECHNICAL CONSIDERATIONS

The characteristics of the vine shoots have been compared with a technical sheet from a consortium in Northeast Italy. Since, in the literature, vine chip is generally reported to have a lower calorific value (LCV) averaging 3.3-3.4 kWh/kg with reference to a 35% moisture content. To confirm this, thanks to recent field experiences by the COAL Cooperative in Motta di Livenza, it is possible to deduce a calorific value of 4.6 kWh/kg for vine chips after an appropriate seasoning process resulting in a 10% moisture content.

This seasoning process begins after harvesting and packaging in the vineyard, as described earlier. Subsequent to harvesting, the bales are stacked in an open area and left uncovered until July, after which the chipping process of the bales of vine shoots can take place.

This activity is necessary to maintain a moisture level below 20%, which is a reference value for mobile grid boilers (Mencarelli et al., 2022), as moisture plays a pivotal role in proper energy content supply (Figure 3.20):

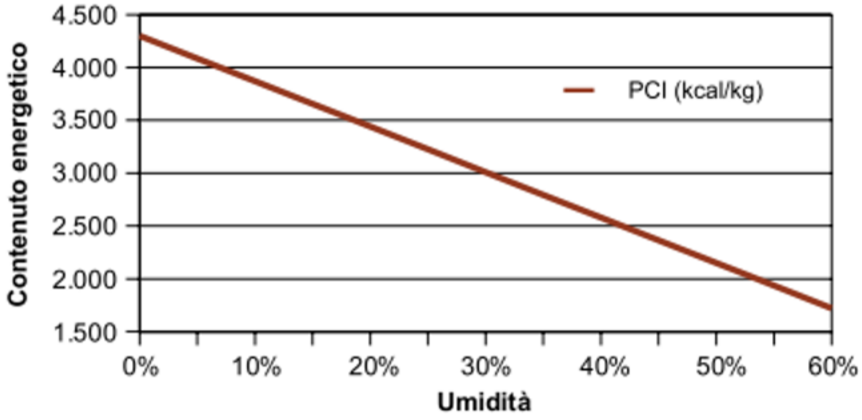


Figure 3.20: Energy content of wood at varying moisture levels

Generally, solid biomass is typically maintained within a moisture range of 10% to 60%, depending on the facility, waste type, boiler type, etc. Figure 3.17 shows that there is an inversely proportional relationship between the energy content and moisture. As highlighted in various experiments, solid biofuel is recommended for use at values around 10-20% (Mencarelli et al., 2022). Therefore, to improve the energy efficiency of the process, natural and forced drying methods have been adopted.

- Natural drying: The raw material is stacked in regular piles that need to be aerated from time to time to prevent degradation. This method requires fire safety regulations in industrial facilities, adequate space, and a suitable climate (low humidity, sunlight, and low precipitation). The final moisture content achieved in this type of drying varies between 15% and 30% depending on the location, which may be excessive for densification.

- Forced drying can take various forms, with the most common being direct dryers (as in the case of Az. Agr.) where heat is provided directly to the material in direct contact with the hot gases exiting from combustion. Other types include rotary drum dryers, belt dryers, and fluid dryers.

The Agricultural Cooperative Society Livenza - COAL conducted a rigorous and comprehensive analysis in an accredited laboratory of the wood chips from the vine branches collected in the member's companies. The analysis was supervised by the Italian Agroforestry Energy Association - AIEL. Table 3.4 reports the values of the main parameters included in the analysis report.

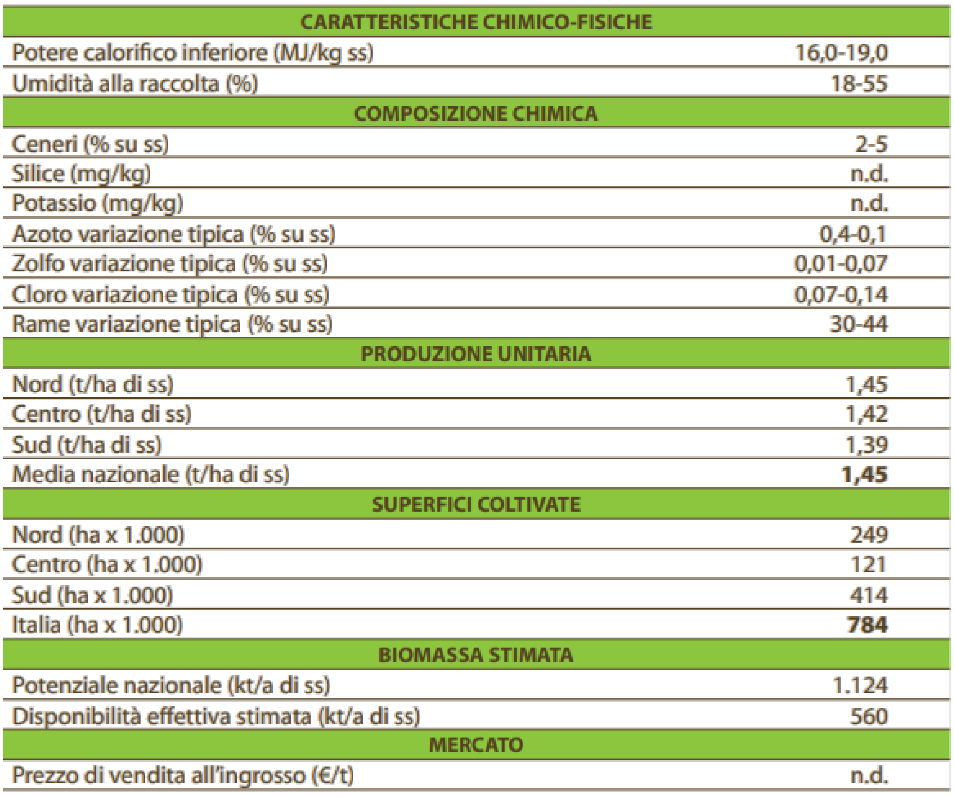
Table 3.4: Main characteristics of Glera vine wood chips (Source: Veneto Agriculture)

Volumetric Mass	213,5 [kg/msr]
Contenent of Water	10 [%]
Lower Heat Value (LHV)	4,6 [kWh/kg]
Size (P)	P 45 [mm]
Energetic density (DE)	982,1 [kWh/msr]

From the "Biomass Project" of the Ministry of Agricultural, Food, and Forestry Policies, where vine branches are characterized with a PCI: 3821 – 4528 Kcal/Kg, it is evident that

Glera vine branches have a potential in line with the national average of other varieties, as shown in Table 3.5.

Table 3.5: Chemical-physical characteristics of Glera vine wood chips (Source: Veneto Agriculture)



CARATTERISTICHE CHIMICO-FISICHE	
Potere calorifico inferiore (MJ/kg ss)	16,0-19,0
Umidità alla raccolta (%)	18-55
COMPOSIZIONE CHIMICA	
Ceneri (% su ss)	2-5
Silice (mg/kg)	n.d.
Potassio (mg/kg)	n.d.
Azoto variazione tipica (% su ss)	0,4-0,1
Zolfo variazione tipica (% su ss)	0,01-0,07
Cloro variazione tipica (% su ss)	0,07-0,14
Rame variazione tipica (% su ss)	30-44
PRODUZIONE UNITARIA	
Nord (t/ha di ss)	1,45
Centro (t/ha di ss)	1,42
Sud (t/ha di ss)	1,39
Media nazionale (t/ha di ss)	**1,45**
SUPERFICI COLTIVATE	
Nord (ha x 1.000)	249
Centro (ha x 1.000)	121
Sud (ha x 1.000)	414
Italia (ha x 1.000)	**784**
BIOMASSA STIMATA	
Potenziale nazionale (kt/a di ss)	1.124
Disponibilità effettiva stimata (kt/a di ss)	560
MERCATO	
Prezzo di vendita all'ingrosso (€/t)	n.d.

The operating principle of the mobile grate boiler focuses on combustion, fueled by vine branches that are transported to the boiler using a conveyance system. This system consistently feeds the boiler with vine branches, ensuring efficient and steady combustion.

Within the combustion chamber, the combustion process takes place, during which vine branches are burned in the presence of air or another oxidizing gas.

A distinguishing feature of this boiler is the mobile grate located in the combustion chamber. This grate consists of bars or elements that can be moved back and forth to transport the vine branches through the combustion chamber. This constant movement serves to ensure uniform combustion of the vine branches, allowing them to burn completely and reducing the formation of ash and deposits.

To achieve efficient combustion, air is supplied to the combustion chamber through two paths: primary air and secondary air. Primary air is usually introduced from the bottom of the mobile grate, while secondary air can be adjusted to control the amount of oxygen available inside the combustion chamber, thereby influencing the speed and efficiency of combustion (Figure 3.21, Figure 3.22)

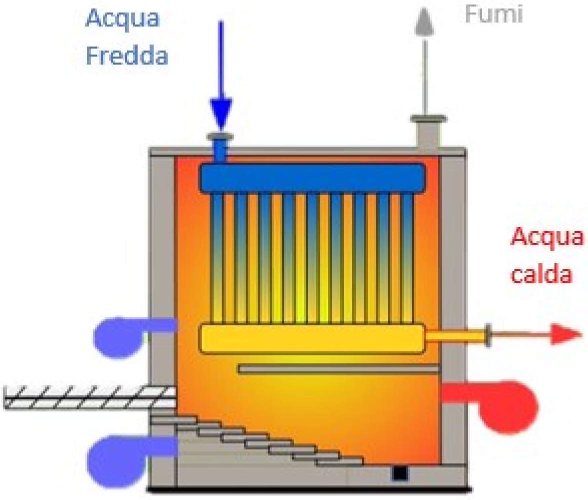


Figure 3.21: Representation of a mobile grate boiler

The heat generated by the combustion of vine shoots is transferred to a heat transfer fluid through a system of heat exchangers. This heated heat transfer fluid is then used for space heating, domestic hot water production, cleaning purposes (e.g., barrel washing), and for the "tunnel" in the phase preceding the labeling of sparkling wines.

Figure 3.22: Tunnel Heating bottles: Dynamic radiant air conditioner

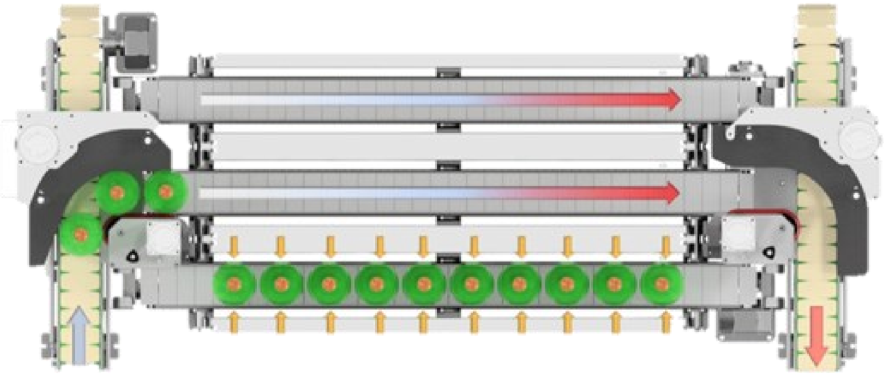


Figure 3.23: Schematic Operation of the Tunnel Heating bottles:

The combustion process and the boiler temperature are controlled by a regulation system that monitors various parameters such as water temperature, air flow, and the rate of vine prunings feeding. This system ensures the efficient and safe operation of the plant.

In summary, thanks to the mobile grate and the regulation system, it is possible to achieve efficient and uniform combustion, minimizing waste and harmful emissions.

Figure 3.24: *Hydraulic system*

In the context of the section dedicated to the "Model and Data," we want to introduce the following subsection that formally outlines the approach used to calculate the thermal energy demand of the agricultural company. In particular, we will analyze the relationship between the annual production of approximately 6 million bottles (including 4 million bottles of Prosecco sparkling wine) and the energy consumption required for the vinification process, based on the value of 1 kWh/hl of thermal energy as reported in a study conducted at the Universidad Politecnica de Madrid (Fuentes-Pila et al., 2015). It should be emphasized how this energy consumption is adapted to the specific company's reality, taking into account the sparkling wine production process. These data are clearly represented in Table 3.6.

Table 3.6: Thermal Energy Demand of the Agricultural Company

Usage	Annual Thermal Demand Kwh
Domestic Hot Water (DHW) (Main office headquarters, Bottling facility office, Owned residence, Processes)	8 000
Heating of Spaces (Head Office, Bottling Plant Office, and Owner's Residence)	30 000
Processes	360 000

ECONOMIC CONSIDERATIONS

To assess the technical and economic feasibility of the entire process, a detailed study was conducted to determine the production cost of vine shoot chips.

Initially, the process and tools can be summarized as described earlier: the vine shoots are pruned during the winter, left in the field, and mechanically collected to form round bales in March. These round bales are then stored in the producers' sheds for 5-6 months, until August. Subsequently, they are chipped and stored in a silo with a capacity of approximately 100 quintals. This silo has been sized to provide about one month's energy supply during the most critical month; therefore, the bales are chipped and stored based on consumption. This silo is equipped with a continuous chip handling system and aeration with hot air from the combustion system. Thanks to this process, it is possible to regulate the moisture content of the product before sending it to the boiler, which, as mentioned earlier, is a critical parameter for process efficiency, avoiding the creation of slag and unburned material.

At the end of combustion, the only output to consider, as a potential cost, is the ash, which is currently used as a fertilizer (about two quintals per month). In general, the use of vine shoot ash as a fertilizer is a sustainable practice that can help reduce disposal costs and improve soil health. Therefore, the cost of ash disposal would not be considered in the cost analysis because it is employed in the field as a pH regulator and a natural source of potassium, calcium, and micronutrients.

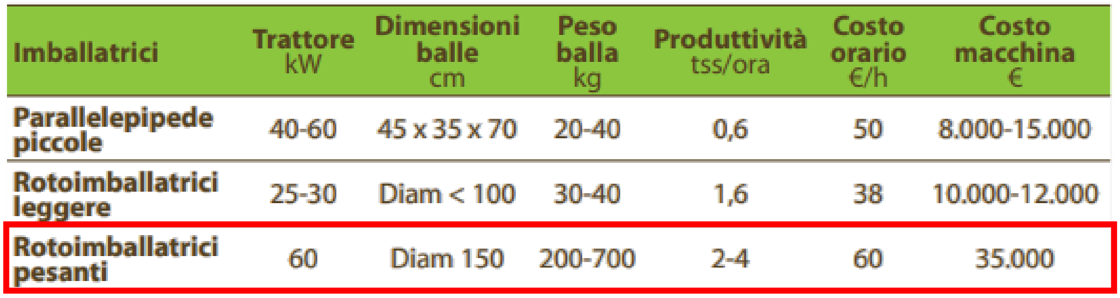
In addition to this cost of ash disposal, which is currently not addressed, there are different considerations for evaluating the economic feasibility. Firstly, since growers deliver the vine shoots, there are no additional costs for transportation or logistics. However, usually, to obtain an accurate assessment of vine shoot chip production costs, the cost of transporting the bales of vine shoots to the storage location should also be considered, but in this case, it is not.

Another consideration concerns the fact that the agricultural company has a baling machine but not a chipping machine, so a comparison of the costs and rates applied by external companies for the chipping process was conducted. However, the ownership of all the equipment by the agricultural company could certainly reduce costs in this phase of the production process.

Regarding the collection and baling service, the agricultural company has entered into an agreement with the local producers, providing them with a baler on a free loan basis with a fixed fee for the collected material, amounting to approximately 50 euros per hectare.

Table 3.6 below shows common types of balers with their main characteristics. The agricultural company has opted for a heavy-duty round baler.

Table 3.6: Common types of balers and key characteristics



Imballatrici	Trattore kW	Dimensioni balle cm	Peso balla kg	Produttività tss/ora	Costo orario €/h	Costo macchina €
Parallelepipede piccole	40-60	45 x 35 x 70	20-40	0,6	50	8.000-15.000
Rotoimballatrici leggere	25-30	Diam < 100	30-40	1,6	38	10.000-12.000
Rotoimballatrici pesanti	60	Diam 150	200-700	2-4	60	35.000

Fonte: Spinelli et al., 2009

Based on the data obtained from the experiments conducted by Veneto Agricoltura, it is estimated that approximately 40 bales can be produced in 8 hours of work, with an average weight of 4 quintals each. Furthermore, taking into account the productivity of the site, the packaging cost is estimated to be around 20 euros per ton (Table 3.5). In the case study, the baler is owned by the company, so it is not considered a direct cost. Unlike chipping, which has an average cost for the company of 33 euros per ton (moisture 10-20%), inclusive of expenses related to fuel, electricity, etc. (G. Cavalaglio et al., 2007).

Comparing these values with those collected in the company, the overall cost for the operations of harvesting, baling, chipping, and storage is estimated to be 70 euros per ton (moisture 10%-20%).

Assuming these data, the agricultural company can source from approximately 60 hectares of Prosecco from its own land and about 20 hectares of Prosecco from suppliers.

As defined earlier, with a productivity of approximately 12 quintals per hectare on a dry basis (10-20% moisture), it is possible to estimate the total amount of vine shoots produced annually, amounting to:

$$q_{vs} = q_{shoots\ per\ hectare} * n_{hectare} = 12 * 80 = 960 \frac{q}{year} \tag{3.1}$$

From this estimate, considering the density of vine shoot chips to be 213 kg/m³ (Table 3.7), and an increment factor of 0.6 for the silo, the silo can be filled 7.5 times in a year, as indicated by the following formula:

$$N_{silos} = \left(\frac{960 * 100}{213 * 0{,}6 * 100}\right) = 7{,}4941\ times\ a\ year \qquad (3.2)$$

Where the annual cost incurred for the processing of this quantity of vine shoots can be estimated at:

$$Cost\quad_{tot.process} = q_{annual\ vs}\left[\frac{q}{annual}\right] * cost\quad_{vs}\left[\frac{euro}{q}\right] = 960\ 7\ = 6720\ euro \qquad (3.3)$$

Table 3.7: Main characteristics of Glera vine wood chips (Source: Veneto Agriculture)

Volumetric Mass	213,5 [kg/msr]
Contenent of Water	10 [%]
Lower Heat Value (LHV)	4,6 [kWh/kg]
Size (P)	P 45 [mm]
Energetic density (DE)	982,1 [kWh/msr]

Given the technical characteristics of the vine shoots, as shown in Table 3.7, and a boiler efficiency of 90%, it is possible to hypothesize a current thermal energy availability amounting to:

$$Q_{net} = PCI * q_{vs} * n_{boiler} = (4{,}6 * 100) * 960 * 0{,}90 = 397\ 440\ kWh \qquad (3.4)$$

$$Q_{available\ per\ silos} = \frac{397\ 440[kWh]}{7{,}4941} = 53062{,}75\_\left[\frac{KWh}{silos}\right]$$

Based on this data and assuming the lower heating value (LHV) of methane is 9.94 kWh/m³, the amount of methane required to equate the net heat output (Q(net)) can be estimated as follows

$$q_{methane} = \frac{Qnet}{PCI_{methane}} = \frac{397\ 440}{9{,}94} = 39983{,}90\ mc \tag{3.5}$$

Taking into account a methane price of 0.75 euros per cubic meter, the expenditure for methane alone to match the thermal potential of the vine prunings is:

$$Cost\ _{methane\ tot.} = q_{meth.} * costo_{meth.} = 39983{,}90 * 0{,}75\ = 29\ 987{,}95\ euro \tag{3.6}$$

Hence, the economic savings achieved by using vine prunings instead of methane are estimated at:

$$Cost\ _{methane\ tot.} - Cost\ _{tot.\ vs} = 29\ 987{,}95 - 6\ 720 = 23\ 267{,}95\ euro \tag{3.7}$$

It is important to highlight that the ratio of LHV between vine prunings and methane is:

$$\frac{PCI_{methane}}{PCI_{vine\ shoots}} = \frac{9{,}94}{4{,}6} = 2{,}16\frac{kg}{mc} \tag{3.8}$$

In light of the previously discussed heating values and costs, the economic advantage in terms of expenditure for every cubic meter of methane replaced with 2.16 kilograms of vine prunings is:

$$Price\ _{meth.} - R_{\frac{meth.}{vs}} * Price\ _{vs} = 0{,}75\ [mc] - 2{,}16\left[\frac{kg}{mc}\right] * 0{,}09\left[\frac{euro}{kg}\right] = 0{,}556\ euro \tag{3.9}$$

Secondly, the adoption of heating systems using biomass always brings environmental benefits as well. It is indeed possible to calculate the reduction in CO2 emissions achievable by replacing fossil fuels with renewable woody fuels.

Considering,

$$Q_{net} = 397{,}440 \text{ kWh} = 397.440 \text{ MWh} \tag{3.10}$$

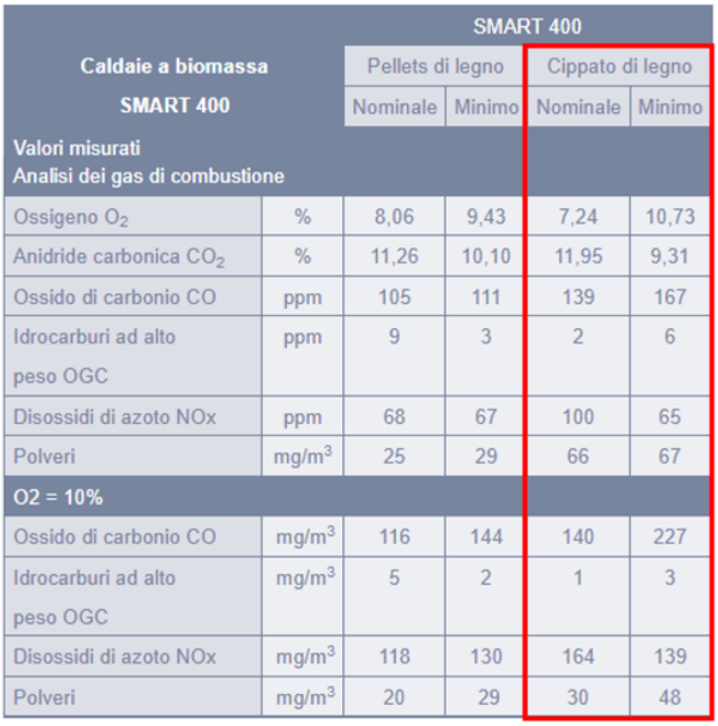
the savings in terms of CO2 can be estimated by using the values from Table 3.8 as follows:

Table 3.8: Average CO2 emissions from the use of methane and grapevine chips (Source: Francescato Valter, Antonini Eliseo, Paniz Annalisa, Berton Marino (2006). Wood and chips. Model chains for the province of Venice. Operational solutions and economic assessments.)

Fuel	C02 (kg/MWh)	C02 eq. (kg/MWh)
Vine shoots	21,12	23,95
Methane (1 MW)	233,96	257,72

However, the values declared by the boiler manufacturer are also provided, as shown in Table 3.9 below:

Table 3.9: Analysis of the fuel gases declared by the boiler's parent company



Caldaie a biomassa SMART 400		**SMART 400**			
		Pellets di legno		Cippato di legno	
		Nominale	Minimo	Nominale	Minimo
Valori misurati Analisi dei gas di combustione					
Ossigeno O_2	%	8,06	9,43	7,24	10,73
Anidride carbonica CO_2	%	11,26	10,10	11,95	9,31
Ossido di carbonio CO	ppm	105	111	139	167
Idrocarburi ad alto peso OGC	ppm	9	3	2	6
Disossidi di azoto NOx	ppm	68	67	100	65
Polveri	mg/m^3	25	29	66	67
O2 = 10%					
Ossido di carbonio CO	mg/m^3	116	144	140	227
Idrocarburi ad alto peso OGC	mg/m^3	5	2	1	3
Disossidi di azoto NOx	mg/m^3	118	130	164	139
Polveri	mg/m^3	20	29	30	48

At this point, in accordance with the information provided by Veneto Agricoltura (Veneto Agricoltura, 2010), we can estimate the CO2 emissions produced by generating 397,440 MWh using methane in one boiler:

$$397{,}440\ MWh * 226{,}81 = 90\ 143{,}3664 \text{ kg of } CO2 = 90{,}143\ t \text{ of } CO2 \qquad (3.11)$$

CO2 emissions for producing 397,440 MWh using grapevine wood chips in one boiler:

$$397{,}440\ MWh * 21{,}12 = 8\ 393{,}9328 \text{ kg of } \mathrm{CO_2} = 8{,}393\ t \text{ of } CO_2 \qquad (3.12)$$

The savings in terms of CO2 achievable in 1 boiler, to produce the thermal energy of 397,440 MWh, by replacing methane with wood chips, is as follows:

$$90.143{,}3664\ -\ 8.393{,}9328 = 81\ 749{,}4336 \text{ kg of } \mathrm{CO2} = 81{,}749\ t\ of\ CO_2 \qquad (3.13)$$

Therefore, for every MWh produced using vine pruning chips instead of methane, there is a savings in terms of tons of CO2 equivalent to:

$$C0_{2_{methane}} - CO_{2_{vs}} = \ 226{,}81 - 21{,}12 = 205{,}69\ \frac{kg\ of\ CO_2}{MWh} \qquad (3.14)$$

The calculation of the return on investment period is not straightforward, as various funds have been received (such as the NEXT Generation EU in 2022, the National Support Plan for the Wine sector in 2021, etc.) for the implementation of not only the plant but also for the installation of the solar-thermal system and the installation and commissioning of a wastewater treatment system. The overall project amounts to approximately 1.5 million euros, of which around 300,000 euros can be attributed to the biomass-fueled energy production system (as revealed in the interviews). As reported in Table 3.11, the Payback Period (calculated using the formula of Boardman et al., 2006) was estimated at 13 years, considering a construction cost of 300,000 euros, net of the average cost of wood chip production and revenue from suppliers.

$$PBP = \frac{300\,000}{29\,987 - (70 * 960) + 1000} = 12{,}4\,years \tag{3.15}$$

Table 3.11: Economic Investment Analysis

Costo realizzazione impianto[1]	300 000 euro
Costo annuo produzione cippato	70 euro/t
Ricavo dai conferitori	1000 euro
Risparmio economico annuo	29 987 euro
Ricavo annuo (al netto delle spese)	23 267 euro
Tempo di ritorno dell'investimento**	13 anni
[1] Comprensivo di: Imballatrice, Quota parte Infrastruttura, Caldaia e relativo impianto di movimentazione della biomassa	

** In the context of the return on investment, it should be specified that the company's thermal energy demand is estimated at around 480 MWh per year (subject to meteorological conditions and variations in orders, etc.). Currently, the vineyard's vine shoots collected in the Prosecco region do not meet the entire demand. Considering the estimated thermal energy demand, the quantity of vine shoots required is as follows:

$$q_{vs} = \frac{480\,000\,kWh}{4{,}6 * 100 * 0{,}9} = 1\,159 \ = 115\,900\,kg$$

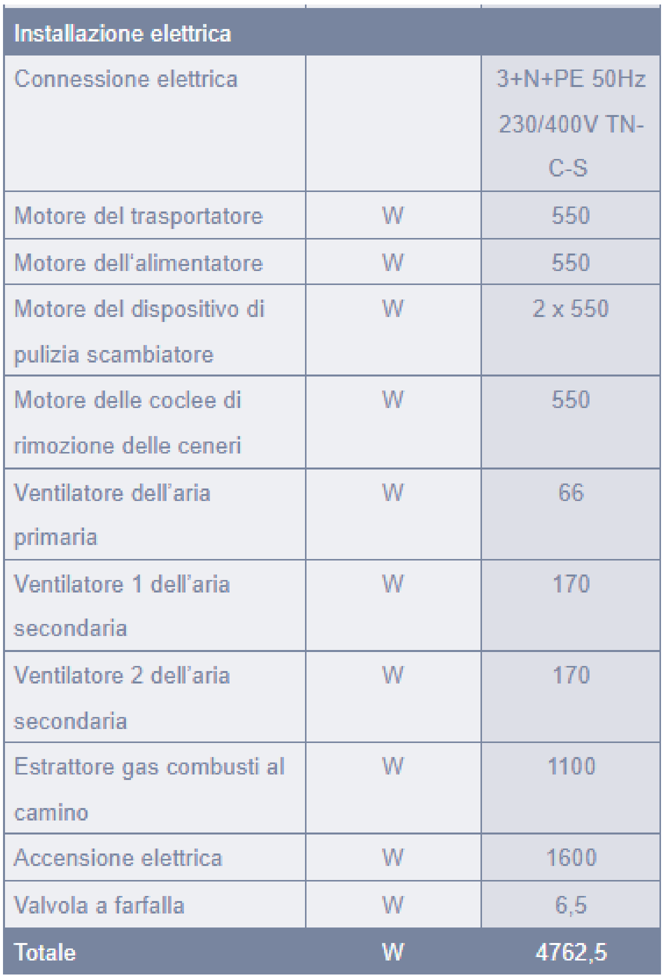
With an economic saving of:

$$Cost\ _{meth.tot.} = \frac{Q_{net}}{PCI_{methane}} * cost\ _{meth} = \frac{480\,000}{9{,}4} * 0{,}75 \ = 38\,297\,euro$$

$$Cost\ _{meth\,tot.} - Cost\ _{tot.lavoraz.} = 38\,297 - (1\,159 * 7) = 30\,184\,euro$$

Finally, the consumption data for the plant is not provided. The boiler consumption data is listed in Table 3.10 below:

Table 3.10: Electricity consumption of the boiler



Installazione elettrica		
Connessione elettrica		3+N+PE 50Hz 230/400V TN-C-S
Motore del trasportatore	W	550
Motore dell'alimentatore	W	550
Motore del dispositivo di pulizia scambiatore	W	2 x 550
Motore delle coclee di rimozione delle ceneri	W	550
Ventilatore dell'aria primaria	W	66
Ventilatore 1 dell'aria secondaria	W	170
Ventilatore 2 dell'aria secondaria	W	170
Estrattore gas combusti al camino	W	1100
Accensione elettrica	W	1600
Valvola a farfalla	W	6,5
Totale	**W**	**4762,5**

Taking into account the operation of the installation for 180 days per year, with 8 working hours per day, the consumption is estimated to be:

$$Energy\ Demand_{EE\ boiler} = 180 * 8 * 4762{,}5 = 6\ 858\ 000\ Wh = 6\ 858\ kWh$$

Recursively, assuming an electricity cost of 0.12 euros per kWh, we will have an electricity expenditure of:

$$Cost\ \ _{EE\ boiler} = 6\ 858\ [kWh] * 0{,}12\ \left[\frac{euro}{kWh}\right] = 822{,}96\,\frac{euro}{year}$$

These data provide a solid foundation for assessing the effectiveness and sustainability of adopting the vine pruning combustion system for thermal energy production on the farm, demonstrating the potential of this practice in terms of energy savings and environmental impact reduction.

4. CASE STUDY: PERLAGE

4.1. PREFACE

The completion of this thesis has provided a fairly comprehensive overview of circular economy applications within the context of viticulture, with a particular focus on the wine sector. In the preceding pages, it is clear how circular economy actions are crucial in shaping the concepts of environmental sustainability and in ensuring new business models in an industry closely tied to climate effects. Specifically, the primary circular economy strategies that vineyard businesses can undertake revolve around two main approaches: managing by-products aimed at retaining organic matter through compost production or burning this organic matter to generate energy.

Both of these paths, however, are not easily navigable for vineyard businesses. Firstly, they require substantial initial investments, and furthermore, they entail management issues directly related to the seasonality of the production process. Although the initial capital obstacle can be overcome, the second hurdle, at the level of an individual company, can only be surmounted under specific conditions. These conditions are related to the quantity of generated by-products. A considerable critical mass of by-products is required to justify investments and ensure an adequate payback. This is one of the reasons why the circular economy struggles to take off in the wine sector.

The problem is related to the way of thinking: as long as the circular economy is viewed only from the perspective of individual companies, it will be genuinely challenging to resolve the problem in the short term. So why not broaden the horizons and look at the issue at the regional level? Here, the combination of problems for individual producers (disposing of by-products, which currently represent a cost to the company) could transform into the answer to the problem itself (creating a community for the recovery and management of waste by-products at the production or regional level).

The case study presented in this thesis has demonstrated that the adoption of the biomass combustion system for energy production is a successful choice in terms of the circular economy. However, to amortize the investment, it is necessary to feed the system not only with vineyard prunings from one's own vineyard but also those from neighboring vineyards and biomass from other sources.

There is one critical point that should not be forgotten. Figure 4.2 reminds us that the action of burning organic matter for energy production has a lower degree of sustainability compared to that associated with recovery and recycling through composting. For this reason, it was decided to present a second, much shorter but particularly significant small case study in terms of comparison. The featured company is Perlage, located in the same region as the Benotto company, and it has chosen the practice of composting instead of combustion. Two similar companies, facing similar problems in the same territory, but with different choices.

4.2. PERLAGE WINERY

Perlage Winery is one of the most prestigious organic wine producers in the Veneto region. It stands out not only for its excellence in organic Prosecco DOCG but also for its social and environmental commitment, transforming wine into a genuine sustainable work of art. Since 1985, the company has embraced a philosophy that goes far beyond wine production, encompassing the concept of a Benefit Corporation. This means the company pursues one or more common benefit goals and operates in a responsible, sustainable, and transparent manner.

Dr. Ivo Nardi, a spokesperson for Perlage, emphasized in the interview that addressing challenges related to ESG (Environment, Social, and Governance) is an increasingly complex yet essential task for the future of his company (Figure 5.1).

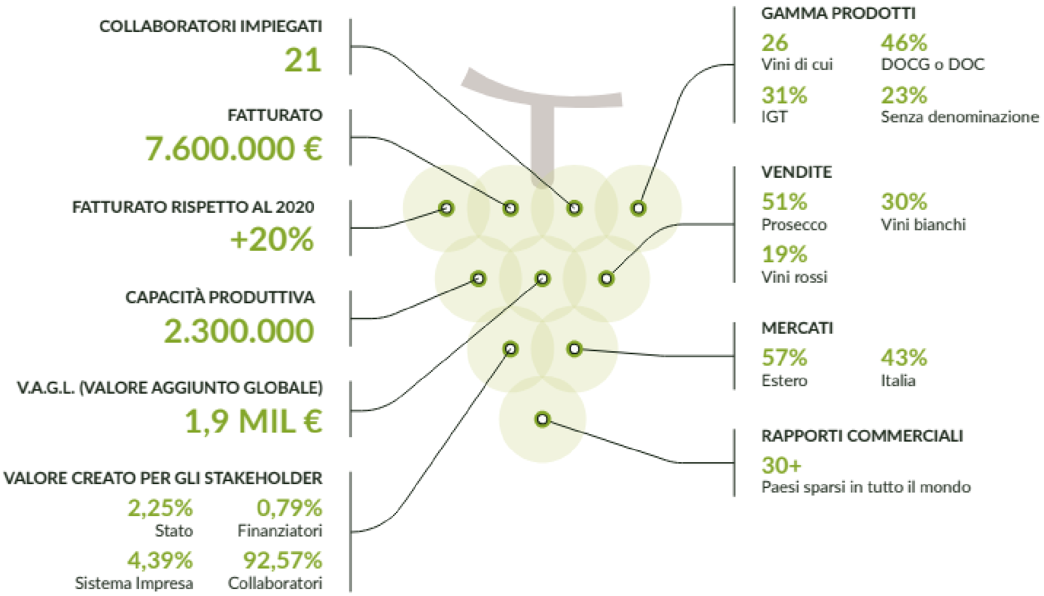
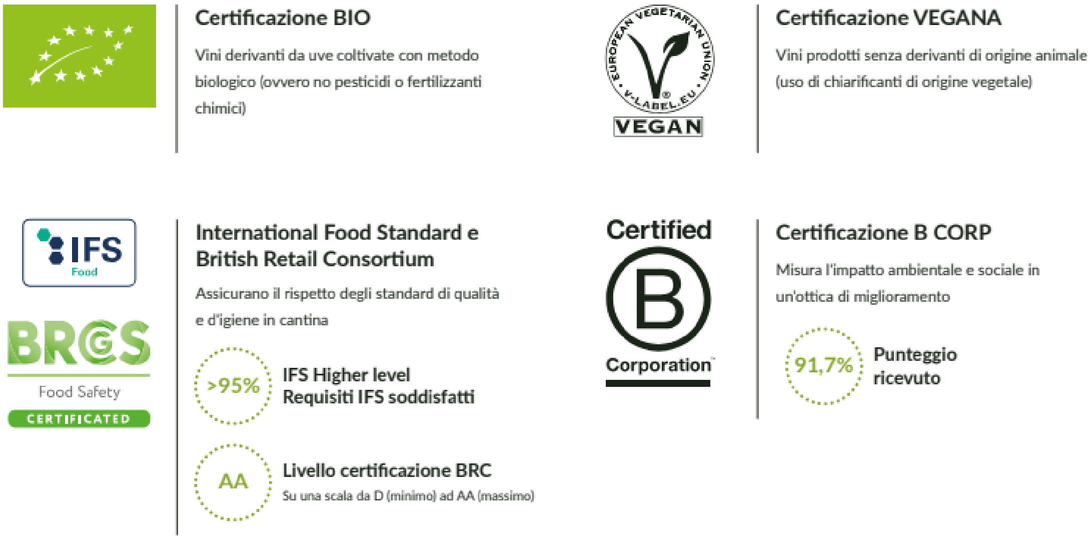


Figure 4.1: Some numbers about the company in 2021

The company's commitment to social responsibility is so strong that in December 2019, the Perlage shareholders unanimously voted for the new bylaws that transformed Perlage into a "Benefit Corporation." Quoting from their sustainability report: *"All the issues we are addressing in terms of ESG, social responsibility, and the environment are becoming increasingly complex. We have a clear vision of where to go, but at the same time, we need to share experiences and knowledge. We are aware that if each of us contributes our part with individual initiatives, the result achieved will have a high impact[...]."*

With these words, Dr. Ivo Nardi introduces the company's fifth sustainability report, which represents a report on the social and environmental impact in line with national regulations, Law 208/2015, governing Benefit Corporations. The sustainability report provides a detailed explanation of the environmental, social, and economic results achieved in 2021 and the improvement actions planned for the future. Perlage has used the B-Impact Assessment as its impact assessment standard so far, but Dr. Ivo Nardi intends to pursue other certifications as he believes that "each certification represents an opportunity to grow and improve[...]." Currently, in addition to organic, BRC, and IFS certifications (Figure 5.2), Perlage is in the process of certification according to the VIVA ministerial standard, the only Italian public standard for measuring and improving the sustainability performance of the wine supply chain.



Certificazione BIO

Vini derivanti da uve coltivate con metodo biologico (ovvero no pesticidi o fertilizzanti chimici)

Certificazione VEGANA

Vini prodotti senza derivanti di origine animale (uso di chiarificanti di origine vegetale)

International Food Standard e British Retail Consortium

Assicurano il rispetto degli standard di qualità e d'igiene in cantina

>95% **IFS Higher level** **Requisiti IFS soddisfatti**

AA **Livello certificazione BRC** Su una scala da D (minimo) ad AA (massimo)

Certificazione B CORP

Misura l'impatto ambientale e sociale in un'ottica di miglioramento

91,7% **Punteggio ricevuto**

Figure 4.2: Certification achived from the company till 2021

Perlage's commitment stems from the awareness of its owners that natural resources are limited, and, for this reason, their preservation is essential to ensure their availability for future generations. It is this very vision that led the company to embrace sustainable practices, with a particular interest in Circular Economy actions. In this regard, Perlage's focus on sustainability in viticulture encompasses the entire production process, from the vineyard to the final bottle. Environmental sustainability is evident in every agronomic practice in the vineyard, which is strictly managed using organic methods, as well as in all phases of winemaking and wine storage, where the company closely monitors energy consumption to minimize carbon footprint impact as much as possible. A recent experiment conducted by the company on a Valdobbiadene sparkling wine called "Canah" has provided valuable insights into the impact of the company's production processes in terms of CO2 emissions (Figure 5.3):

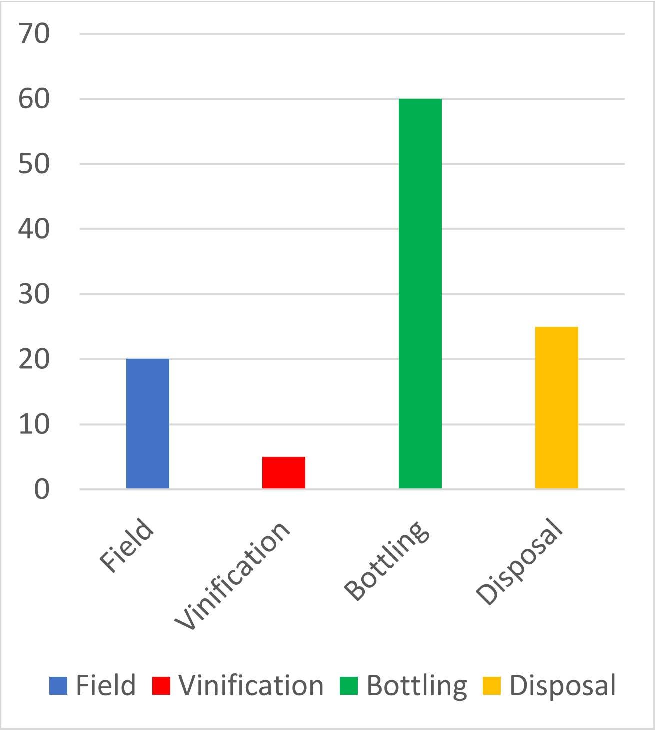


Figure 4.3: Kq di CO_2 eq. for the production of a Prosecco's bottle

The chart is quite comprehensive and demonstrates that the main impact in terms of emissions is attributed to bottling, followed by the vineyard.

From the interview, it became apparent that the company is aware of the need to address challenges, starting right from the vineyard. Indeed, Dr. Nardi has observed for some time that rescue interventions in the vineyard are becoming increasingly frequent. This is because plants are more frequently under stress due to water scarcity, rising temperatures, and excess non-useful water (caused by downpours, which do more harm than good). These observations have been the driving force behind the company's changes over the years, shaping a corporate philosophy that aims primarily at reducing emissions and respecting and enhancing the organic matter in its vineyard habitat. According to Dr. Nardi, chemical fertilization simply has an instant effect, whereas the adoption of organic compost allows for carbon sequestration and provides the soil with a lasting structure that enhances the quality of the wines produced, compensating for the growing plant stress situations.

This green vision of the company is confirmed by a path that began approximately 30 years ago, in times when it was not yet common, with the decision not to use chemical fertilizers but only "organic" ones to improve soil fertility.

The drivers that have guided Perlage towards continuous improvement over the years are based on three key points:

- Reduction of CO2;
- Reuse of resources;
- Engagement of personnel and the community.

With regard to the reduction of CO2, Perlage has set a goal to become carbon neutral, meaning to eliminate its carbon dioxide emissions, by 2030, 20 years ahead of the goals set by the Paris Agreement.

Among the various actions and projects carried out by Perlage, the following are highlighted:

- Reducing fuel consumption, for example, the fuel generated by employees commuting to the company. The company attempted to offer a 1,500 euro contribution for those who switched to an electric car. The incentive did not work adequately because the contribution was too residual compared to the increase in the cost of electric cars that occurred in recent years.
- Purchase of an electric tractor to reduce CO2 emissions associated with fieldwork.
- Increasing the fermentation temperature from 16°C to 19°C to reduce the need for cooling in the cellar.
- Adopting pruning waste composting systems in the vineyard.

This last topic deserves specific attention. Perlage's winery began composting grapevine prunings as early as 2016, an action initiated following the controversy over burning vine shoots in the hilly area of Valdobbiadene (around 2010), a common practice in the hilly areas of Valdobbiadene. Composting, or biostabilization, is a biological aerobic process that leads to the production of a mixture of humified substances (compost) from green, woody, or animal residues. According to what is defined in article 22 of the DM of

February 25, 2016, digestate from "non-waste" intended for agricultural use can be produced through: a) straw, clippings, and pruning; b) agricultural material derived from agricultural crops; c) livestock effluents; d) wastewater; e) residues from agri-food activities; f) olive mill vegetation waters and wet pomaces, including pitted ones; g) by-products of animal origin; h) agricultural and forestry material not intended for food consumption.

Literature (Lot, 2013) highlights that, on average, pruning vineyards can yield woody biomass of about 25 quintals/hectare/year (with a 50% moisture content). Considering that during the composting process, there is a loss of mass (mainly water and carbon dioxide) of about 20% of the initial mass, approximately 15-20 quintals of wet compost per hectare can be quantified.

As Perlage owns a vineyard area of 15 hectares (15 Ha), it can be seen that its production is around 375 quintals of woody biomass per year, which corresponds to about 200 quintals of wet compost per year.

The process begins with chipping and simultaneous collection of dry pruning shoots in the field, usually in March, followed by on-field storage. The composting process lasts two years:

- In the first year (from March onwards), the shoots are accumulated outdoors in the vineyard to initiate the first fermentation in the pile. It is preferable to work with pruned shoots as soon as possible when they still have a good moisture content and have not started to dry out. Moisture is essential to facilitate the initiation of biological processes in the mass to be composted. As shown in Figure 5.4, it is advisable to find a suitable composting site that can be located near trees to control sun exposure during the summer, making the drying process slower and, if possible, watering the mass if it is not sufficiently moist inside.
- In the second year, a composted mixed amendment allowed in organic farming is added to accelerate the activity of microorganisms and complete the composting process.

Figure 4.4: A) Vine compost after one year of composting. B) Mixed compost after two years of composting

However, the pile composting practice employed by Perlage has some disadvantages that need to be considered. To prevent anaerobic decay processes, regular maintenance is required to keep the mass sufficiently aerated and avoid water stagnation. Additionally, the pile needs to be mixed every time the internal temperature drops below approximately 50 degrees Celsius. This is because aerobic microorganisms significantly reduce their activity at low temperatures, even to the point of death at temperatures below 5°C and above 70°C.

On the positive side of this practice, it should be noted that compost piles often reach temperature peaks of 60-65°C, triggering a brief sanitation process of the composted material to reduce potential proliferation and spread of pathogens. This practice allows for the "sanitization" of the prunings from any contaminations that, if simply spread in the vineyard, would continue to spread within the company's vineyards, compromising vineyard health and final product quality.

Furthermore, through this practice, Perlage is able to obtain approximately 200 quintals of wet compost in total, which amounts to about 13 quintals of wet compost per hectare of vineyard, with an economic value of approximately 130 euros per hectare.

The compost obtained in this way should be distributed in generous layers at regular intervals: typically, the company divides its vineyard area into 3-4 parts, and each year, all the available compost is spread on one-third/fourth of the area in rotation.

According to the analyses conducted by Perlage at the end of the pile fermentation process, the compost values obtained fall within those specified by the regulations (Table 5.1, Table 5.2), making them suitable for spreading in the vineyard. This allows the company to successfully adopt a particularly virtuous circular economy practice.

Table 4.1: Additional Requirements for Eligibility in Organic Farming Pursuant to Annex 13, Part Two of Legislative Decree 29/04/2012 No. 75

Element	Udm: mg/kg
(Cd)	Max 0.7
(Ni)	Max 25
(Cu)	Max 70
(Pb)	Max 45
(Zn)	Max 100
(Cr)	Max 70
(Cr VI)	0

Table 4.2: Mixed composted amendment from Fertilizer Registry No. 009276/15 Bio comp Contarina

	Udm: mg/kg
Relative Humidity	Min 30%
PH	8
Organic Carbon (C) (% s.s)	Min 20%
Carbon (C)	Min 7%
(N) (% s.s di N tot)	Min 80%
(C)/(N)	Min 2%

To facilitate the moistening of the pruning residue pile and reduce the water footprint in the vineyard, Perlage has also chosen to create rainwater recovery ponds, with the aim of mitigating the effects of climate change through a network of surface drainage.

These water basins have a capacity of 1500 hectoliters and serve the purpose of collecting rainwater, as rainfall events are becoming increasingly frequent in shorter time intervals (the so-called "cloudbursts"). Thanks to these storage systems, it is possible to plan irrigation interventions uniformly across all vineyard plots through a capillary distribution system (Figure 5.5).

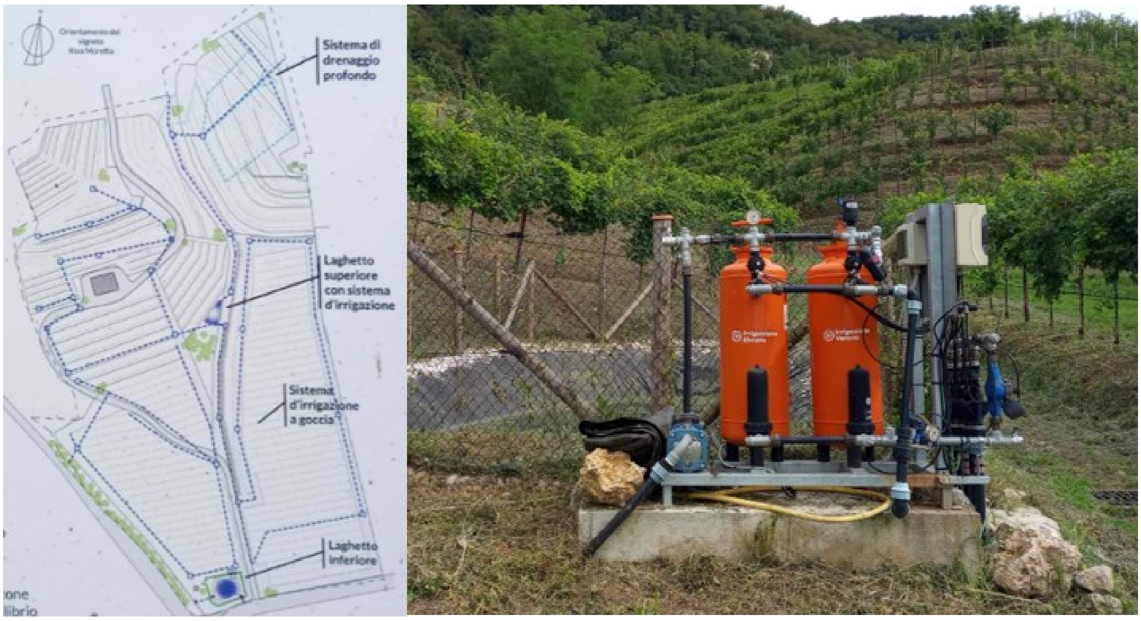


Figure 4.5: Rainwater Recovery System and Cloudburst Prevention

CONCLUSION

This thesis has highlighted that the analysis of the scientific literature underlying the concepts of Circular Economy and Circular Business Models is extensive and, in specific contexts, particularly in-depth. When focusing on the industrial sector, these topics have been addressed both theoretically and practically for many years, demonstrating the robustness of the model and the scientific validity of the results achieved. However, the search for cross-sector applications of these techniques, even in less conventional sectors such as viticulture, has not yielded particularly significant results. The same can be said for the literature related to the transformation within the winery context, as technological applications are still quite limited and often in the experimental stage.

In the viticultural context, circular economy concepts are often discussed mainly in a theoretical sense, while practical applications are limited. When rare case studies of circular economy applications in the world of wine are discussed, they are mostly qualitative and only occasionally quantitative. Even the author of this thesis, in developing case studies, faced significant challenges in finding data to support what emerged from interviews.

If we consider potential applications in viticulture emerging from the literature, opportunities for companies are abundant. However, a critical dimension arises based on the type of circular economy actions adopted, and it becomes a key question. Given the seasonality of production, is it truly feasible for individual companies within the viticultural sector to implement circular economy actions? Is there a critical scale for specific circular economy actions that allows a company to obtain tangible benefits with appropriate payback times? Or is it more cost-effective to apply circular economy principles at the regional level, thereby triggering a virtuous cycle not only for individual companies but for the entire operating territory?

The case study examined, that of Agr. Benotto, in some way helps answer these questions. Agr. Benotto is currently one of the very few companies within the Prosecco DOCG region to have adopted such a comprehensive system for biomass combustion for energy production.

The case study emphasizes that, to make Dr. Benotto's investment truly profitable, it was not enough to solely feed the system with shoots from his own vineyard. He also had to use:

- Shoots from vineyards and olive groves from another company, also owned by the Benotto family, located in Puglia. In this case, in addition to vine shoots, olive pruning residues were also collected and used.

- Vine shoots from some neighboring producers who had the opportunity to dispose of these by-products with limited monetary expenditure. Clearly, this choice was made to address a question at the regional level that Agr. Benotto managed to intercept. Shoot disposal, as mentioned several times, is subject to some issues: first of all, by law, open-field burning of piles is no longer allowed. Secondly, shredding and spreading in the vineyard incurs costs for the company and can lead to the persistence of vine contaminant agents in the environment. Therefore, outsourcing shoot disposal to third parties is currently the most appropriate choice for the Valdobbiadene region.

It is natural to wonder if, after the entire process, the quantification of the carbon footprint related to the collection, shipment, and management of the bales used compensates, beyond mere economic savings, for the environmental benefits obtained from the recovery and combustion of biomass. Clearly, answering this question would require conducting a thorough Life Cycle Assessment (LCA) or carbon footprint analysis of the processes involved, which is beyond the scope of this study. However, it is worth asking the question because it could be a stimulus for future studies in this direction.

Organizationally, the case study highlights how the implementation of sustainable practices at the company and regional levels, while beneficial, also comes with complexities. First of all, the technical and logistical organization of the supply chain requires a significant effort. Agr. Benotto had to plan and implement actions related to the collection, transportation, and storage of shoot bales first directly at the suppliers' companies and then at his own company. This required not only finding and creating adequate storage space for shoot bales but also defining work protocols and concluding collaboration agreements between the suppliers and Agr. Benotto. It should also be noted that the adoption of biomass combustion and energy recovery technologies is often not well-received by the local population, which is rightly concerned about the level of emissions and the implications of these choices for public health, not to mention the impact on the landscape.

Despite these challenges, the Agr. Benotto case study has shown that the involvement of Prosecco DOCG's supply chain actors is essential, almost necessary, to address the challenges related to the success of local initiatives focused on environmental sustainability. Collaboration between producers, supply chain operators, and local authorities represents the focal point for implementing an integrated management of by-products, waste reduction, and the promotion of sustainable practices. To increase the number of actors involved in the project and pursue greater economic sustainability of the investment, it is necessary to share experiences, disseminate results adequately, and share best practices identified. Sharing information allows learning from others and adopting proven solutions, fighting disinformation, and reducing the time associated with learning curves. Through structured collaboration, supply chain actors can provide mutual support in by-product management and the implementation of circular economy practices.

Of course, all that has been said so far cannot truly materialize at the regional level until there is strong political will on the part of the protection consortia. The Prosecco DOCG supply chain consortia themselves could be the first to benefit from this shift toward circular economy policies at the regional level, assuming a coordinating role and pursuing innovative environmental policies at the regional level. This integration could even receive financial support and incentives from the European Union, which periodically funds initiatives to support sustainable transition.

The most significant limitation, as highlighted in the case study, in terms of involving actors in the Prosecco DOCG supply chain in the transition to circular economy policies, is resistance to change. According to what emerged from the interview with Dr. Benotto, the majority of the supply chain actors still prefer to continue pursuing traditional methods. Often, these choices are primarily due to a lack of awareness regarding the real advantages and disadvantages of adopting specific circular economy techniques.

To support this point, the thesis aims to contribute by identifying a SWOT analysis concerning the biomass combustion system for energy production.

Figure 0.1: SWOT analysis

Strengths:

1. Abundant Resources: The agricultural company has access to a potential abundant source of vine shoots, which can be harnessed.
2. Environmental Sustainability: The energy utilization of vine shoots represents an ecologically sound approach, contributing to agricultural waste reduction and the production of renewable energy.
3. Supply Chain Collaboration: Collaboration with producers and the sharing of best practices, as demonstrated in the case of Benotto, has facilitated the implementation of sustainable practices.
4. Pioneering Spirit: Being the first company to adopt a vine shoot energy utilization system in the region can lead to a position of leadership and a competitive advantage.

5. Disposal of Olive or Wood Residues for Third Parties: In addition to vine shoots, the company also utilizes olive wood from properties in Puglia. Therefore, other fuels can be harnessed, proposing a disposal service similar to that provided for producers but targeted at local entities (e.g., wood residues).
6. Funding for Sustainable Agriculture: €80,000 has been granted through the national support plan for the wine sector – EU Reg. No. 1308/2013, Article 50. Biennial notice 2022-2023. DGR No. 1245 of September 14, 2021, invested in this plant.

Weaknesses:

1. Technologies and Infrastructure: The adoption of technologies for vine shoot energy utilization required significant initial investments in equipment and infrastructure, which need to be amortized.
2. Technical Knowledge: Efficient management of energy utilization processes requires specific technical knowledge, initially not present within the company.
3. Resistance to Change: As highlighted in the Benotto case, resistance to change among supply chain actors can pose a challenge to the adoption of sustainable practices.
4. Legislation and Regulations: Bureaucratic procedures with the municipality were lengthy and costly.

Opportunities:

1. Energy Savings: The use of vine shoots for energy production results in long-term energy cost savings for the agricultural company.
2. Income Source Diversification: Vine shoot energy utilization could represent an additional source of income for the company, e.g., through the sale of surplus energy.
3. Brand Reputation: The company can leverage vine shoot energy utilization as a strength in promoting its image as an environmentally responsible agricultural company.
4. Broader Collaboration: Expanding collaboration among supply chain actors could lead to greater economic sustainability of investments and the sharing of best practices.

5. Support from the European Community: By adhering to circular economy policies, financial support and incentives from the European Community can be obtained. For example, the integration of protection consortia could receive financial support from the European Community to promote innovative environmental policies.
6. Disease Control: The removal of vine shoots from the vineyard can contribute to disease control, improving the health of the vines.
7. Exportability of the Model: The company owns several plots in Puglia with olive and vine trees. It is possible to consider exporting the knowledge gained in this initiative for the implementation of another plant.
8. Bureaucratic Simplification: This aspect could be further investigated to assess how to simplify and expedite approval and regulatory compliance processes, allowing agricultural companies to more easily adopt sustainable practices like vine shoot energy utilization.

Threats:

1. Energy Market Fluctuations: Energy price fluctuations and market conditions can impact the profitability of the investment.
2. Environmental Regulations: Changes in environmental regulations can significantly impact energy utilization operations, requiring costly compliance.
3. Local Competition: Other agricultural companies in the area might compete for similar resources, creating competition for available vine shoots.
4. Resistance to Change: The resistance to change by supply chain actors represents a significant threat to the adoption of new circular economy practices or the expansion of the current business.
5. Organizational Complexity: The implementation of sustainable practices requires significant organizational effort, including logistical issues and collaboration agreements. Infrastructure, for example, may be insufficient if the agricultural company intends to expand, necessitating additional investments in silos.
6. In summary, vine shoot energy utilization offers the agricultural company an opportunity to improve its sustainability, reduce long-term energy costs, and diversify income sources. However, initial investments are required, collaboration

among supply chain actors is crucial, and careful attention to environmental issues is necessary to address the challenges associated with this initiative. One more point that needs to be addressed. Agricultural company Benotto has made a choice, identifying biomass combustion for energy production as a possible solution to environmental sustainability. However, it should be remembered that the European Community has clearly expressed its stance on the circular economy, and as shown in Figure 4.2, energy recovery ranks among the lower levels of the sustainability pyramid, just after reduction, reuse, and recycling.

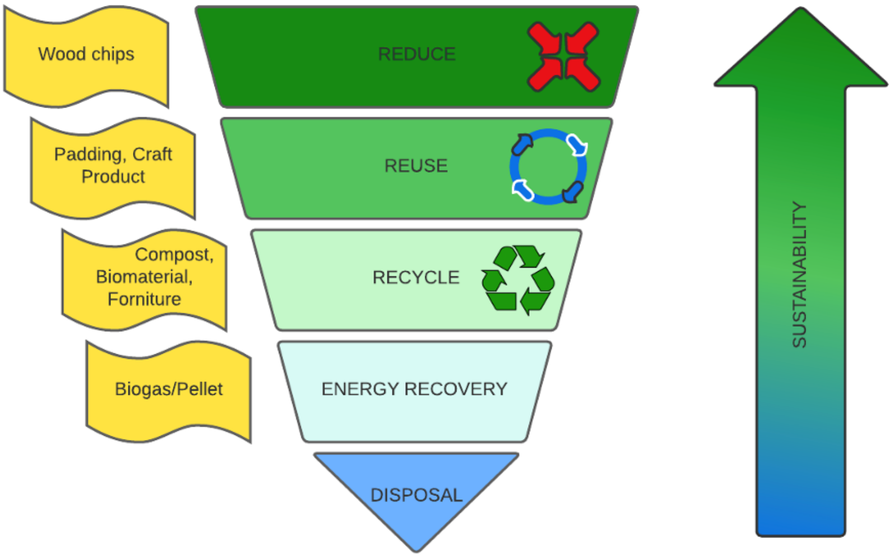


Figure 0.2: Zero Waste Hierarchy from the pov of vine shoots

According to this logic, the higher one positions oneself on the pyramid, the more virtuous the level of sustainability in business choices, ultimately reaching the pinnacle which involves adopting methodologies aimed at waste prevention.

As previously mentioned in the literature analysis chapter, it is possible to encourage the use of additional circular economy techniques. An example is composting, where pruning residues can be used to create natural fertilizer for application in vineyards, thus improving soil health and plant fertility. This choice is considered more virtuous than vine shoot combustion because it allows the preservation of organic matter, which is scarce in nature and should be conserved for future generations. The case study in the appendix demonstrates how the choice of composting within the Prosecco region is a viable alternative, resulting in a quality product to be used as a soil conditioner in vineyards.

Moreover, there are other circular economy actions that have not been analyzed in the case studies but deserve consideration: without significant initial investment costs, it is indeed possible to create synergy with the local artisan and furniture community by using winery by-products to craft furnishings and furniture (e.g., using wine barrels to make tables or house flooring). If the company had the capacity to internally process the by-products, it could even transform them into high-value-added products, such as dietary supplements or cosmetics. In this scenario, the valorization of by-products represents an opportunity to diversify core activities and allows for a substantial increase in profits from ancillary activities.

In the future, the economic feasibility of by-product reuse will also depend on market demand for these types of products. It is important for the company to develop its capacity to assess and respond to the demand for products like compost, bioactive products, or other derivatives from wine-related by-products. If there is a stable and profitable demand for these products, it will increasingly make the reuse of by-products along the supply chain economically viable.

Finally, it is essential to emphasize that the economic feasibility of by-product reuse should not be evaluated solely in terms of immediate profits but should also consider the long-term value of environmental sustainability and social responsibility. By reusing by-products and introducing circular business models, it can contribute to the positive image of the company, improve its reputation, and create long-term business opportunities.

5. WEBSITES CONSULTED

Accessed on: 07/07/2023

https://www.beverfood.com/sostenibilita-aziende-vinicole-italiane-wd/

Accessed on:11/07/2023

https://enologicapetrillo.it/valorizzazione-dei-sottoprodotti-della-filiera-vitivinicola/

Accessed on: 15/08/2023

https://agriregionieuropa.univpm.it/it/content/article/31/27/la-catena-del-valore-nella-filiera-vitivinicola

Accessed on: 09/09/2023

https://www.studocu.com/en-us/document/studocu
university/filosofia/feuerbach/22672114

Accessed on: 23/08/2023

https://www.istat.it/it/dati-analisi-e-prodotti/visualizzazioni/grafici-interattivi

Accessed on: 15/08/2023

https://www.istat.it/it/archivio/16777

Accessed on: 05/09/2023

https://www.ispionline.it/it/pubblicazione/ispitel-fact-checking-migrazioni-2021-31027

Accessed on: 22/06/2023

https://www.greenplanner.it/2020/11/19/smaltimento-rifiuti-plastici/

Accessed on:16/06/2023

https://www.ilsole24ore.com/art/raccolta-rifiuti-l-italia-sommersa-la-paralisi-totale-AEa0DKNG

Accessed on:09/09/2023

https://www.repubblica.it/green-and
blue/2022/10/14/news/rifiuti_elettronici_raee_smaltimento-370030683/

Accessed on: 23/08/2023

https://unric.org/it/obiettivo-12-garantire-modelli-sostenibili-di-produzione-e-di-consumo/

Accessed on:18/07/2023

https://www.istat.it/it/files//2020/06/Sostenibilit%C3%A0-nelle-imprese.pdf

Accessed on: 09/09/2023

https://www.wolterskluwer.com/it-it/expert-insights/piano-di-sostenibilita-come-si-fa

Accessed on: 22/08/2023

https://www.4sustainability.it/le-tre-r-dell-economia-circolare/

Accessed on: 03/08/2023

http://osservatoriosharingmobility.it/wp-content/uploads/2019/07/come-sta-la-sharingmobility_III-Rapporto-SM_13-e-FRONT.pdf

Accessed on: 25/08/2023

https://www.ucm.es/data/cont/docs/76-2023-07-11-29_Tesla_coil.pdf

Accessed on: 23/09/2023

6. REFERENCES

Arzoumanidis, I., Fullana-I-Palmer, P., Raggi, A., Gazulla, C., Raugei, M., Benveniste, G., & Anglada, M. (2014). Unresolved issues in the accounting of biogenic carbon exchanges in the wine sector. In *Journal of Cleaner Production* (Vol. 82, pp. 16–22). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2014.06.073

Beni, C., Felici, B., Aromolo, R., Marcucci, A., & Pierandrei, F. (2005, August). *Utilizzo di fertilizzanti a base di borlanda vitivinicola su cavolo broccolo: effetti sulla qualità del suolo e sulla produzione*.

Bietresato, M., Ciotti, G., Zironi, A., Zironi, R., Gubiani, R. (2023). Proposal for methodology to analyse operability of wine production plant in terms of power demand. *Engineering for rural development*, 473-478.

Bioplastiche dai sottoprodotti della vinificazione: sostenibilità ambientale ed economica. (2019). https://www.researchgate.net/publication/333385897

Brenna, S., Caserini, S., Di Milano, P., Acutis, M., & Perego, A. (2017). Il contributo dello stoccaggio di carbonio nei suoli agricoli alla mitigazione del cambiamento climatico. https://doi.org/10.14672/ida.v4i2.1200

Veneto Agricoltura. (2010). L'uso energetico dei sarmenti della vite.

Cavalaglio, G., Cotana, S., Barbanera, M., & Giraldi, D. (2007). Valorizzazione energetica degli scarti di potatura *dei vigneti*.

Consorzio di Tutela DOC. (2023). *Export Prosecco*. https://www.prosecco.wine/it/news/prosecco-doc-anche-il-2022-si-chiude-con-un-segno-positivo

Consorzio di tutela DOC. (2023). *Produzione di Prosecco DOC*. https://www.prosecco.wine/it/news/prosecco-doc-anche-il-2022-si-chiude-con-un-segno-positivo

Corbo, C., Sogari, G., Macconi, M., Menozzi, D., & Mora, C. (2014). Vino sostenibile: l'atteggiamento dei consumatori italiani. *Agriregionieuropa*, *10*.

Correia, M. (2019). Sustainability: An Overview of the Triple Bottom Line and Sustainability Implementation. *International Journal of Strategic Engineering*, *2*, 29–38. https://doi.org/10.4018/IJoSE.2019010103

Cotana, F., & Cavalaglio, G. (2023). Impianto Pilota per la Conversione Energetica degli Scarti di Potatura dei Vigneti.

Devesa-Rey, R., Vecino, X., Varela-Alende, J. L., Barral, M. T., Cruz, J. M., & Moldes, A. B. (2011). Valorization of winery waste vs. the costs of not recycling. Waste Management, 31(11), 2327–2335. https://doi.org/10.1016/j.wasman.2011.06.001

D'Alessandro termotecnica, Manuale d'uso e manutenzione - caldaie serie CSL, v.10

DNV. (2019). La Sostenibilità nella Vitivinicoltura in Italia.

Fuentes-Pila, J.; Garcia, J.L.; Murcho, D.; Baptista, F.J. Best practices for improving energy efficiency (in agro industries). in TESLA project (Transfering Energy Save Laid on Agroindustry), november 2015

Garibaldi, R. (2021). Rapporto sul Turismo Enogastronomico Italiano: Trend e tendenze.

Geissdoerfer, M., Pieroni, M., Pigosso, D., & Soufani, K. (2020). Circular business models: A review. *Journal of Cleaner Production*, *277*, 123741. https://doi.org/10.1016/j.jclepro.2020.123741

Guilbaud, P., Lecomte, P., & Louvet, G. (2005). *Le compostage des sarments. Une nouvelle mesure prophylactique pour lutter contre les maladies du bois*.

Guogang, J., Chen, J., (2011). *Research on evaluation of circular economy development. In: Proceedings of the 8th International Conference on Innovation & Management*. Kitakyushu, Japan, p. 153-157.

Haas, W., Krausmann, F., Wiedenhofer, D., Heinz, M., (2015*). How circular is the global Economy?: an assessment of material flows, waste production, and recycling in the European union and the World in 2005: how circular is the global economy?* J. Ind. Ecol. 19, p. 765-777.

Horbach, Jens, Klaus Rennings, and Katrin Sommerfeld, (2015)."*Circular economy and employment." In 3rd IZA Workshop: Labor Market Effects of Environmental Policies.* Tratto da: http://conference.iza.org/conference_files/environ_2015/horbach_j11332.pdf

Huysman, S., De Schaepmeester, J., Ragaert, K., Dewulf, J., De Meester, S., (2017). *Performance indicators for a circular economy: a case study on post-industrial plastic wast*e. Resour. Conserv. Recycl. 120, p. 46–54.

ICESP, Gdl 3, (2018). "*Strumenti per la misurazione della circolarità".* Tratto da: https://www.icesp.it/landing/docs/gdl/gdl3/REPORT_GdL3%20Strumenti%20per%20la%20misurazione%20dell%E2%80%99economia%20circolare.pdf

ISEMA, (2019). Scheda di settore 2019.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M., (2018*). Barriers to the circular economy: evidence from the European Union (EU).* Ecological Economics, 150, p. 264-272.

Korhonen, J., Honkasalo, A., & Seppälä, J., (2018*). Circular economy: the concept and its limitations. Ecological economics*, 143, 37-46.

Kristensen, H. S., & Mosgaard, M. A., (2019). *A review of micro level indicators for a circular economy–moving away from the three dimensions of sustainability.* Journal of Cleaner Production, 118531.

Lawton, K., (2013). *European Commission: The opportunities to business of improving resource efficiency.* Tratto da: https://ketlib.lib.unipi.gr/xmlui/bitstream/handle/ket/1024/The%20opportunities%20to%20business%20of%20improving%20resource%20efficiency%20Annexes.pdf?sequence=2&isAllowe d=y

Lacy, P., Rutqvist, J., & Lamonica, B. (2016). *Circular Economy: Dallo spreco al valore*. EGEA spa. Capitolo 4.1

Leip, A., Billen, G., Garnier, J., Grizzetti, B., Lassaletta, L., Reis, S., ... & Westhoek, H., (2015). *Impacts of European livestock production: nitrogen, sulphur, phosphorus and greenhouse gas emissions, land-use, water eutrophication and biodiversity*. Environmental Research

Letters, 10(11), 115004. Li, R.H., Su, C.H., (2012). *Evaluation of the circular economy development level of Chinese chemical enterprises.* Proced. Environ. Sci. p. 13, 1595-1601.

Linder, M., & Williander, M., (2017). *Circular business model innovation: inherent uncertainties. Business strategy and the environment*, 26(2), p. 182-196

Linder, M., Sarasini, S., van Loon, P., (2017). *A metric for quantifying product-level circularity*. J. Ind. Ecol. 21, 545–558.

Lot, A. (2013), *Proposte per il compostaggio dei sarmenti di vite*, Ufficio Ambiente del Comune di Pieve di Soligo.

Mariani, A., Napoletano, F., Pomarici, E., & Tedesco, R. (2005). *Valutazione della competitività del settore vitivinicolo italiano: un contributo all'analisi. Economia e Diritto Agroalimentare*, 3.

Meier, M. S., Stoessel, F., Jungbluth, N., Juraske, R., Schader, C., & Stolze, M. (2015). *Environmental impacts of organic and conventional agricultural products–Are the differences captured by life cycle assessment Journal of environmental management, 149, 193-208.*

McKinsey, G., (2011). Resource Revolution: Meeting the world's energy, materials, food, and water needs. Global Institute and Sustainability & Resource Productivity Practice. Tratto da: https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Resource%20revolution/MGI_Resource_revolution_full_report.ashx

Milano, P. DI. (n.d.). Analisi tecnico-economica di un moderno impianto di generazione elettrica da energie rinnovabili (biomasse).

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., ... & Dewulf, J. (2019). *Circular economy indicators: What do they measure?. Resources, Conservation and Recycling, 146, p. 452-461.*

Moriguchi, Y., (2007). Material flow indicators to measure progress toward a sound materialcycle society. *Journal of Material Cycles and Waste Management, 9(2), p. 112-120.*

Park, J.Y., Chertow, M.R., (2014). Establishing and testing the "reuse potenti al" indicator for magagni Waste as resources. J. Environ. Manag. 137, p. 45-53.

Pauliuk, S., (2018). Critical appraisal of the circular economy standard BS 8001:2017 and a dashboard of quantitative system indicators for its implementation in organizations. Resour. Conserv. Recycl. 129, p. 81–92 109

Pizzol, L., Luzzani, G., Criscione, P., Barro, L., Bagnoli, C., & Capri, E. (2021). The Role of Corporate Social Responsibility in the Wine Industry: The Case Study of Veneto and Friuli Venezia Giulia. *Sustainability*, *13*(23). https://doi.org/10.3390/su132313230

Puglia, M., Pedrazzi, S., Allesina, G., Morselli, N., & Tartarini, P. (2017). Vine prunings biomass as fuel in wood stoves for thermal power production. *International Journal of Heat and Technology*, *35*, S96–S101. https://doi.org/10.18280/ijht.35Sp0113

Potting, J., Hanemaaijer, A., Delahaye, R., Ganzevles, J., Hoekstra, R., & Lijzen, J., (2018). *Circular Economy: What We Want to Know and Can Measure-System and Baseline Assessment for Monitoring the Progress of the Circular Economy in the Netherlands. PBL Netherlands Environmental Assessment Agency: Hage, The Netherlands*. Tratto da: file:///C:/Users/User/Downloads/circular-economy-what-we-want-to-know-and-can-measure2018-netherlands.pdf

Poore, J., & Nemecek, T., (2018). *Reducing food's environmental impacts through producers and consumers. Science*, 360(6392), p. 987-992.

Prieto-Sandoval, V., Jaca, C., & Ormazabal, M., (2018). *Towards a consensus on the circular economy. Journal of Cleaner Production*, 179, p. 605-615.

Qing, Y., Qiongqiong, G., Mingyue, C., (2011). *Study and integrative evaluation on the development of circular economy of Shaanxi province*. Energy Proced. 5, p. 1568-1578.

Urbinati, A., Chiaroni, D., & Chiesa, V., (2017). *Towards a new taxonomy of circular economy business models. Journal of Cleaner Production, 168, p. 487-498.*

UNEP (United Nations Environmental Programme), (2017). *"Resource efficiency: potenti al and economic implications", A Report of the International Resource Panel.* Tratto da: https://www.resourcepanel.org/sites/default/files/documents/document/media/resource_efficiency_report_march_2017_web_res.pdf

Roadmap, R. E., (2011). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions. Roadmap to a Resource Efficient Europe*, Brussels, 20, 2011. Tratto da:

https://www.europarl.europa.eu/meetdocs/2009_2014/documents/com/com_com(2011)0571_/com_com(2011)0571_en.pdf

Rocchi, *Measuring circularity: an application of modified Material Circularity Indicator to Agricultural system*.

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A., (2017). *Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Managemen*t, 16, p. 145-163.

Regione Veneto. (2021). *Valutazione Ambientale Strategica*.

Rex Dufour. (2018). Assessing the soil resource for beginning organic farmers.

Scheepens, A.E., Vogtländer, J.G., Brezet, J.C., (2016). *Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems. Case: making water tourism more sustainable*. J. Clean. Prod. 114, p. 257–268. 110

Scidev. (2019). *Soil health key to achieving SDGs*.

Scientifici, I. P., Italiana, C., & Gorizia, A. (n.d.). *Vitis Energetica Valorizzazione energetica dei sarmenti di vite in provincia di Gorizia,* I partner imprenditoriali.

Siebrecht, N. (2020). Sustainable Agriculture and Its Implementation Gap—Overcoming Obstacles to Implementation. *Sustainability*, *29*, 3853. https://doi.org/10.3390/su12093853

Silvestri, M. (2020). *Sviluppo sostenibile: un problema di definizione*.

Silvestrini G., (2017). *Beyond linear economic patterns. Rivista eco-scienza*. Tratto da: https://www.arpae.it/cms3/documenti/_cerca_doc/ecoscienza/ecoscienza2017_2/ENG/Silvestrini_es2017_2ENG.pdf

Sehnem, S., Vazquez-Brust, D., Pereira, S. C. F., & Campos, L. M., (2019). *Circular economy: benefits, impacts and overlapping*. Supply Chain Management: An International Journal.

Skunca, D., Tomasevic, I., & Djekic, I. (2015). *Environmental performance of the poultry meat chain–LCA approach*. Procedia Food Science, 5, 258-261.

Soli, V. (2017). *Il settore avicolo: problematiche e ruolo delle imprese leader, lavorare in AIA*. In Lavorare in AIA. Edizioni Ca'Foscari. p. 23-37.

Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). *A review of the circular economy in China: moving from rhetoric to implementation. Journal of cleaner production*, 42, p. 215-227.

Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., Rosales, M., Rosales, M., & de Haan, C., (2006). *Livestock's long shadow: environmental issues and options. Food & Agriculture* Org. Tratto da: Tratto da: http://www.fao.org/3/a-a0701e.pdf

Stefanon, B., & Mele, M., (2018*). Allevamento animale e sostenibilità ambientale: Le tecnologie*. G. Pulina (Ed.). FrancoAngeli, p. 369-371.

Statista. (2022). *Wine production by country*. https://www.statista.com/markets/421/agriculture/

UN General Assembly. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*.

Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What Is Sustainable Agriculture? A Systematic Review. *Sustainability*, *2015*, 7833–7865. https://doi.org/10.3390/su7067833

Van Zanten, H. H., Van Ittersum, M. K., & De Boer, I. J., (2019). *The role of farm animals in a circular food system. Global Food Security*, 21, p. 18-22.

Vanegas, P., Peeters, J.R., Cattrysse, D., Tecchio, P., Ardente, F., Mathieux, F., Dewulf, W., Duflou, J.R., (2018). *Ease of disassembly of products to support circular economy strategies*. Resour. Conserv. Recycl. 135, p. 323–334 Environmental impacts and sustainability of egg production systems. Poultry Science, 90(1), p.263-277.

Veneto Agricoltura. (2010). *L'uso energetico dei sarmenti della vite*.

Vinidea Srl. (2021). *Linee guida per il compostaggio ed l'utilizzo dei rifiuti solidi di cantina*.

Yang, L., Xiao, X., & Gu, K. (2021). Agricultural Waste Recycling Optimization of Family Farms Based on Environmental Management Accounting in Rural China. *Sustainability*, *13*, 5515.

Wen, Z., Meng, X., (2015). *Quantitative assessment of industrial symbiosis for the promotion of circular economy: a case study of the printed circuit boards industry in China's Suzhou New District*. J. Clean. Prod. 90, p. 211-219.

Zaman, A.U., Lehmann, S., (2013). *The zero waste index: a performance measurement tool for waste management systems in a "zero waste city.*" J. Clean. Prod. 50, p. 123-132.

Zink, T., Geyer, R., Startz, R., (2016). *A market-based framework for quantifying displaced production from recycling or reuse*. J. Ind. Ecol. 20, p. 719–729.