

Article

Introduction of Renewable Energy in the Spanish Wine Sector

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Abstract: The wine sector is very sensitive to the effects of climate change. Despite this, there is little use of renewable energy in the wine sector. In fact, the adoption of mitigation measures by companies depends on their own attitudes and interests. The objective of this work was to understand the use and disposition of Spanish wineries to incorporate renewable energy. In addition, subjective obstacles to and motivations for adoption could be identified. First, a survey was conducted on the Spanish wine sector. Second, the multivariate statistical technique of factor analysis was applied. Third, a set of indicators to describe the determinant factors that influence a winery's decision to adopt renewable energy was obtained. Finally, a cluster analysis provided three different profiles. The first group comprised wineries that did not trust on the maturity of renewable energy. The second one comprised wineries that were not convinced about introducing renewable energy, either for environmental or reputational reasons. The third group comprised wineries convinced of the benefits of incorporating renewable energy. This work was done as a part of the European project: Renewable Energy in the Wine Industry (LIFE REWIND).

Keywords: renewable energy; sustainability; wine sector; viticulture; wineries; survey; CO₂ emissions; cluster analysis

1. Introduction

1.1. Energy and Climate Change

Energy production from fossil fuels is the biggest source of greenhouse gases, which contribute to climate change and global warming. This damage is continuous but silent, and the responsibility is widely distributed and little assumed. In addition, the fact that energy production is external to the business seems to avoid the concern of companies in nonenergy economic sectors. Therefore, it is very desirable that companies be concerned not only with reducing their energy consumption, but also about the source of that energy. Thus, a sectoral approach to the use and source of energy could be useful.

The effects of climate change are predicted to impact the agricultural sector in coming decades [1], affecting this sector and all of its associated industries. Meanwhile, most agricultural tools and equipment are driven by fossil fuels, which are the main source of greenhouse gases (GHGs) accelerating global warming [2]. The use of fossil fuels, either mobile or at fixed locations, produces pollutant emissions, such as carbon dioxide (CO₂), carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile hydrocarbons (HC), and solid particles (C+). Moreover, by accident

or by mismanagement, losses of fuel, lubricants, and other substances and polluting residues (filters of air and fuel, etc.) occur. At the same time, engines are a source of noise pollution. As one of the main sources, agricultural systems contribute between 19% and 29% of global anthropogenic GHG emissions [3].

1.2. The Wine Sector and Its Energy Use

Agribusiness is one sector with high energy consumption; in fact, its consumption accounted for 26% of the EU total in 2013, and 28% of this consumption came directly from industrial processes [4]. This means that 7.3% of all the energy consumed in the EU goes toward the production of food and beverages. In addition, Spain is among the five European countries with a larger food and beverage industry (the others are Germany, France, Italy, and the United Kingdom), and therefore is among the countries with higher energy consumption. In this way, the introduction of renewable energy would be associated with cost reduction and environmental improvement.

The wine industry is at risk for substantial climate-related threats [5]. Global warming has many effects on wine [6,7]. First, high temperatures during vine growing exert a negative effect on grape composition and wine quality. Second, ripening is accelerated, leading in turn to excessive sugar accumulation in grapes and an increase of 50% in alcohol level in the wines. Finally, there is faster depletion of organic acids in the grape juice, which increases pH value. As a result, the general flavor profile may undergo an atypical change toward overmatured. For these reasons, important adaptation measures might have to be implemented [8,9].

Additional risks are related to the consequences to revenues and production costs throughout the supply chain [10]. Modifying production processes due to climate variability and extreme events, may lead to additional socioeconomic impacts for the whole sector and its related activities [11]. Some studies [12,13] address the main areas of environmental concern, currently facing wine organizations. These authors agree that the most relevant environmental aspects, include but are not limited to the following: water use and management, organic and inorganic solid waste, energy use and greenhouse gas emissions, air quality, agrochemicals, land use issues, and biodiversity.

This paper is focused on the perception of sustainability and the use of renewable energy in the wine sector. In fact, climate change and energy are now two sides of the same coin, i.e., most of the greenhouse gas emissions come from the use of energy. This is due to the presence of nonrenewable resources in the current generation mix.

Although this fact is not usually taken into account, the wine sector consumes large amounts of energy in the different phases of winemaking: grape growing, vinification, bottling, and distribution [14]. As a result, the industry is responsible for the emission of a large quantity of CO₂. Nowadays, most of the energy used in the wine sector (mainly electricity and diesel) is produced from nonrenewable energy sources. Therefore, reducing CO₂ emissions requires a change in the energy system, with a greater proportion of renewables in the energy mix. In fact, evidence suggests that it takes approximately 2618 GJ of energy to process one ton of grapes into the finished product, and for every standard bottle of wine produced, between 0.41 kg and 1.6 kg of CO₂ is released into the atmosphere [15]. Wine distribution and postproduction logistics are also carbon intensive, due in part to the reliance on heavy and bulky forms of packaging [16].

According to the necessary reduction of greenhouse gas emissions, the European Union has promoted the use of renewable energy sources through several directives, establishing a common framework for the production and promotion of renewable energy. In this sense, three key targets have been set for the year 2020, i.e., 20% cut in greenhouse gas emissions (from 1990 levels), 20% of EU energy from renewables, and 20% improvement in energy efficiency. Moreover, the 2030 climate and energy framework sets higher targets for the year 2030, i.e., at least a 40% cut in greenhouse gas emissions (from 1990 levels), 27% share of renewable energy, and 27% improvement in energy efficiency [17].

1.3. The Spanish Wine Sector

The wine sector has great importance due to its economic, social, cultural, and environmental value throughout the world and across Europe, as well as in Spain. In fact, according to data from the International Organization of Vine and Wine (OIV), in 2016 the total world area under vines reached 7.52 million ha; European vineyards occupy an area of 3.3 million ha, and Spain has 975,000 hectares under vines [18]. Spain is the country with the largest wine area (i.e., 13% of global and 30% of European vineyard area) (Figure 1). Out of the 975,000 hectares, 95.4% goes to the production of wine grapes; 33% of Spanish vineyards are irrigated (333,459 ha) and occupy 10% of the total agricultural area nationwide.

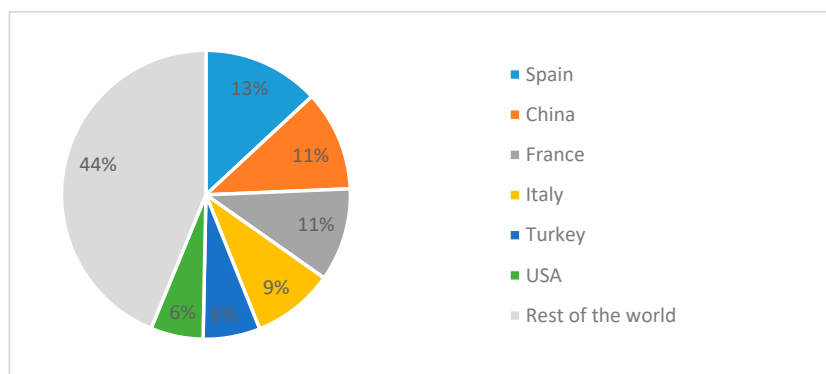


Figure 1. World area under vines by country.

Global wine production (excluding juice and must) is 267 million hl, and the EU vinified production is likely to reach 162 million hl. Spain, with 39.4 million hl, is the third-largest wine producing country in the world (Figure 2).

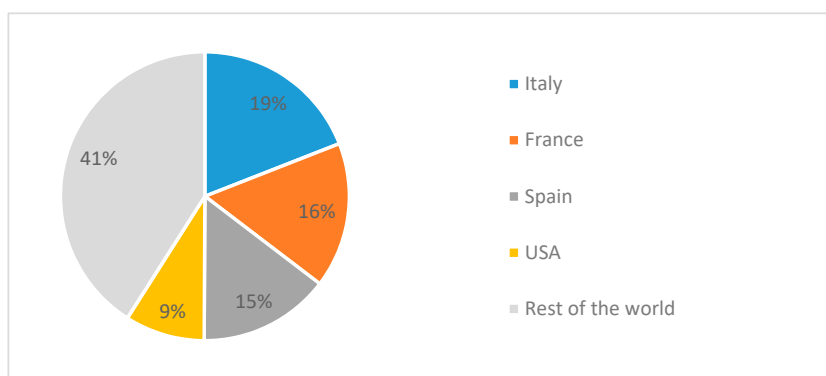


Figure 2. World wine production by country.

Despite the importance of this industry in Spain, it also should be mentioned that the wine sector has been shrinking in recent years in favor of countries from the “new world” (in the vitivinicultural context). These include the United States, Australia, New Zealand, China, Argentina, Chile, etc. Therefore, Spain has to be in a constant search for alternatives to stay at the elite level of international trade. Along these lines, the origin denominations have been a key factor in giving greater popularity to those countries’ wines. In addition, diversification of the sector with activities of restoration, recreation, etc., are intended to promote the variety of their wines, as well as to look for new ways to expand their products in the market. In this context of searching for new business alternatives, Spanish wineries and vineyards must integrate sustainable development and eco-efficiency. Building construction may

include the concepts of sustainable development associated with energy and water management aspects, i.e., thermal insulation, renewable energy, and water-saving technologies.

1.4. Penetration of Renewable Energy in the Spanish Wine Sector

Several barriers have hindered the widespread adoption of renewable energy [19]. One barrier is the relatively high initial investment. However, profitability must be analyzed in the medium and long term. Conventional energy sources become more expensive over time, due to the cost of purchasing electricity or fuel. In contrast, renewables become less expensive, because once the infrastructure is built, the sun and wind provide free resources. Furthermore, renewable energy technologies are being rapidly improved by continuously increasing their cost efficiency. As a result, at vineyards or wineries, renewable energy could be economically competitive [20], even more so in locations far from electricity grids [21]. In fact, public subsidies for renewable energy are declining and will gradually disappear. Despite this, it is almost certain that the policy will continue to favor a transition to renewable energy. In summary, the economic difficulty will be limited to obtaining financing for an investment, which will be amortized over a few years.

As far as energy independence and security of supply is concerned, Spain has a very high dependence on imported oil, gas, and nuclear fuel [22]. In general, energy security requires a confident supply, at a stable and competitive price over time. In rural areas where the wine activities are carried out, quality of supply by the power grid is not always guaranteed and is always very expensive.

1.5. From Attitudes to Innovations in the Wine Sector

The decision-making process for incorporating innovations in companies is not obvious [23]. In addition to mandatory rules, there are many other factors that can play a role in inducing change [24], including the attitudes of managers and stakeholders [25]. Managers' perception refers to their subjective personal evaluation of the attributes of innovation. This perception is used to assess whether an innovation offers increased benefits over the technology that one intends to replace.

On the one hand, adopting innovations that provide environmental improvements is a process strongly influenced by profitability. While some may be profitable, others are not, although they may be necessary from a social and environmental point of view. Adoption depends on a range of personal, social, cultural, and economic factors, as well as on characteristics of the innovation itself [26]. Understanding the factors of adopting innovations is important to design programs which favor it. This also helps in finding out why other programs have not worked as well as expected [27]. A study carried out among dairy farmers showed that their decisions about the environmental practices they used on their farms were based on a pragmatic evaluation of the production context, that is, the decisions of farmers about adopting these practices were not strongly influenced by their attitudes on sustainability and the environment [28].

On the other hand, a factor of interest to wineries regarding the environment is market demand [29,30]. The environmental awareness of customers is increasing, and more wine consumers have an environmentally friendly lifestyle. In this sense, the image of a sustainable product with a small carbon footprint can be appreciated. The perception of sustainability in other countries has been addressed [31,32], but this work is especially focused on the use of renewable energy. In another direction, there are studies [33] which question whether innovations in wine are well received by consumers, as they can break from the traditional product image associated with wines from the old world. This doubt does not affect the case that concerns us, namely, the substitution of fossil fuel-based energy for renewable energy, given that this does not change the winemaking process or the quality of wine. Depending on the market niche that the winery wants to reach, it may or may not incorporate this innovation in the image of its wines.

With all that said, the objective of this work was to understand the disposition of the Spanish wine sector to incorporate renewable energy. Our aim was to know which of the mentioned determinant factors influence wineries in Spain, to adopt or not adopt, renewable energy.

The adoption of innovations for sustainability by the wine sector has been addressed by multiple studies [27,34–36]. In general, the energy part has been limited to reducing consumption involved in the production of wine. In contrast, this work focused on a specific action: replacing conventional energy with energy of renewable origin. In this sense, it is a work that can be seen from two different angles. On the one hand, from the vitivini cultural point of view, it tackles a concrete way of reducing the carbon footprint, without intervening in the winemaking process. On the other hand, from the energy point of view, it shows a path to advance the transition to renewables through a specific production sector.

This work is framed within the European project Renewable Energy in the Wine Industry (LIFE REWIND), which addresses the technical and economic feasibility of using renewable energy produced on site in agricultural activities. It also shows that it is possible to use hydrogen in transport and agricultural machinery [37], including producing hydrogen from renewable energy on the farm itself [38]. The scope of that project is very broad, including technical, economic, energy, environmental, and socioeconomic approaches. From the multidisciplinary LIFE REWIND project, and from other works in the energy field, the feasibility and profitability of incorporating renewable energy in wineries and vineyards has been addressed. The purpose of this work was to know the point of view of companies in the sector, to identify actions that can facilitate this change.

2. Materials and Methods

Statistical Methodology: First, a survey was conducted in the Spanish wine sector. Second, the multivariate statistical technique of factor analysis was applied. Third, a set of indicators was obtained to describe the decision factors. Finally, a cluster analysis provided 3 different profiles.

2.1. Sample of Wineries

According to the System of Analysis of Iberian Balances (SABI) [39], an online database that contains financial information on 940,000 Spanish and 100,000 Portuguese companies, the Spanish wine map in 2016 was formed by 3894 wineries. To have a photo of the Spanish wine sector, we decided to use a simple random sample of 87 wineries, stratified by region, corresponding to a confidence level of 94% and an error rate of 10%. Table 1 presents the final sample of wineries, and Figure 3 their geographic locations.

Table 1. Number of wineries and sample size by Spanish region.

Spanish Regions	Number of Wineries	Sample Wineries
Andalucía	287	7
Aragón	144	3
Asturias	19	0
Baleares	57	1
Canarias	84	2
Cantabria	5	0
Castilla-León	597	13
Castilla-La Mancha	445	10
Cataluña	603	13
Extremadura	118	3
Galicia	342	8
La Rioja	326	7
Madrid	195	4
Murcia	87	2
Navarra	116	3
País Vasco	261	6
Valencia	208	5
Total	3894	87



Figure 3. Locations of surveyed wineries.

2.2. Questionnaire

According to the usual practice of creating a questionnaire, several winery owners were asked to identify the key aspects and the most relevant characteristics of this sector. This process involved semi-structured and in-depth interviews. The definitive questionnaire includes various blocks, as shown in Table 2.

Table 2. Questionnaire blocks.

Block	Topic
I	Identification and location
II	Company activity
III	Company's environmental policy
IV	Attitude on climate change
V	Renewable energy use and attitude
VI	Use and consumption of nonrenewable energy

- I. The first block of questions identified and located the wineries by name, municipality, and province; the wine area they belong to, the year they were established, the majority shareholders, and the legal form of the company.
- II. The second block of questions were about the company's activity. This involved questions on the number of employees, turnover volume, and gross floor area, to establish whether it was a large or small winery. Wineries were also questioned on the percentage of different qualities of wine they produced and of the foreign market sales out of their total sales. Another important issue was establishing whether they performed additional activities, and what percentage these represent of their total turnover. Furthermore, of interest was learning where the grapes used in producing their wine came from; in other words, whether the grapes were their own, or they came from vine growers with or without a contract, or from cooperatives. It was obviously important to discover how many hectares were involved, and whether they participated in their management whilst the crop was growing.
- III. The third block of questions focused on environmental responsibility and policy. Wineries were asked if they had any organic winemaking certification, if they had calculated the carbon footprint of their activity or products, if they conducted energy audits, and if they had their own resources to manage the company's environmental policy.

- IV. The fourth block of questions was aimed at analyzing wineries' attitudes on climate change. The purpose was to know whether the wineries were convinced that the climate had changed, and what their level of willingness was to reduce their CO₂ emissions. We were interested in finding out, which measures they had already adopted.
- V. The fifth block included questions on renewable energy. The companies were asked about the type of energy they used, whether they were convinced of the need to use renewables, their opinion on the outlay for implementing them, and the aspects they valued to adopt their use, such as reliability, environmental sustainability, grants, and the impact on their image.
- VI. The last block of questions was aimed at knowing whether the use of renewable energy was technically and economically viable. Consequently, questions were included on the use and consumption of non-renewables, especially electricity, diesel, and gas. Wineries were asked about their consumption trend throughout the year, their level of concern for energy costs, and whether they had reviewed invoices and the power usage stated in their contract, with a view to reducing it.

Given that our objective was to discover the penetration of renewable energy in the Spanish wine sector, this paper was focused on the questions of block V. The relevant questions were related to the opinions of wineries about using renewable energy, the cost of implementing it, and the motivations to adopt it.

2.3. Descriptions of the Variables

To create a concise and easy-to-answer questionnaire, very few questions were asked, specifically, conviction of using renewable energy; opinion on the cost of renewable energy implementation (i.e., investment, maintenance, and operational costs); and motivations to adopt the use of renewable energy (i.e., reliability, environmental sustainability, existence of subsidies, and corporate image). The variables were as follows:

- **Convinced use:** This variable measured, on a 0–10 scale, the degree of agreement of the winery with the need to use renewable energy. A score of 0 indicated that the winery strongly disagreed, and 10 that it strongly agreed.
- **Investment:** This variable measured, on a 0–10 scale, the winery's perception of the importance of the investment associated with implementing renewable energy. A score of 0 indicated that the winery thinks it is a very small expense, and 10 that the expense is very high.
- **Operational costs:** This variable measured, on a 0–10 scale, the winery's perception of the dimension of operational costs associated with adopting renewable energies. A score of 0 indicated that the winery thinks it is a very small expense, and 10 that the expense is very high.
- **Maintenance costs:** This variable measured, on a 0–10 scale, the winery's perception of the dimension of maintenance costs associated with adopting renewable energy. A score of 0 indicated that the winery thinks it is a very small expense, and 10 that the expense is very high.
- **Grants:** This variable measured, on a 0–10 scale, the importance the winery gives to the existence of subsidies for adopting renewable energy. A score of 0 indicated that the winery considered the existence of subsidies unimportant, and 10 that it was very important.
- **Image:** This variable measured, on a 0–10 scale, the importance of the effect on the corporate image of adopting renewable energy. A score of 0 indicated that the winery considered the impact unimportant, and 10 that it was very important.
- **Reliability:** This variable measured, on a 0–10 scale, the importance that the winery gives to the reliability of renewable energy at the time of deciding on its adoption. A score of 0 indicated that the winery considered it unimportant, and 10 that it was very important.
- **Sustainability:** This variable measured, on a 0–10 scale, the importance that the winery gives to sustainability in its decision to implement renewable energy. A score of 0 indicated that the winery considered it unimportant, and 10 that it was very important.

The mean values and standard deviations obtained, for each of these variables in the sample of selected wineries, are shown in Section 3.2.

The answers provided by the wineries were manually coded and processed using the Statistical Package for Social Sciences (SPSS). Applying the multivariate statistical technique of factor analysis, a set of indicators which allowed us to describe the determinant factors influencing the implementation of renewable energy was constructed. Factor analysis is one of the most commonly used interdependency techniques. It is utilized when the relevant set of variables shows a systematic interdependence, and the objective is to find the underlying latent factors, permitting a reduction of the set of variables. In the case of the present work, this technique allowed a reduction from the previous 8 variables to 4 factors. The estimation method used was principal components, together with an orthogonal varimax rotation. The main 4 factors explained 77.4% of the total variability of the 8 variables, as shown in Section 3.3.

3. Results

3.1. Description of the Sample

3.1.1. Company Activity

Winery staff size is very varied, with an average of 15 people. Fifty percent of wineries have more than seven employees. The average turnover volume is € 5,358,365, and 50% of wineries have a volume above € 1 million. The average wine production is 206,120.88 hl, and 50% of the analyzed wineries had production over 2800 hl. Approximately 51% of wineries obtain their income only from the wine they produce, and the remaining 49% obtain additional income from other activities. Nevertheless, their revenue for additional activities represents less than 10% of turnover in 71% of the cases, which means these activities are peripheral to the winery's main business.

Of the wineries in the sample, 43% had relationships with external vine growers. As a result, 82% of these wineries participated in management of the viticulture. On average, the vineyard area providing grapes to wineries is 29.18 ha. The survey also allowed analysis of the characteristics and activities of the vineyards, because 81% of the wineries owned them. In addition to vines, 33% of the land included some other crops.

Regarding the vineyards, 85% were rain-fed; for 16% of these, their owners intended to incorporate irrigation systems. These companies gave several reasons for transforming rain-fed vineyards into irrigated ones, as shown in Table 3. Reasons given by companies that did not plan to incorporate irrigation are shown in Table 4.

Table 3. Reasons given by companies that plan to incorporate irrigation.

Reason to Incorporate Irrigation	Percentage (%)
Assure/improve grape quality	80
Compensate for rainfall variations	40
Increase grape production	40

Table 4. Reasons given by companies that do not plan to incorporate irrigation.

Reason to Not Incorporate Irrigation	Percentage (%)
Type of wine produced	53
Maintain traditions	30
Respect the microclimate of the vineyard	25
Lack of water	20
Administrative difficulties	8
No electricity available	3
Other (including appellation of origin rules)	15

3.1.2. The Company's Environmental Policy

Only 28% of wineries in the sample had any kind organic or ecologic certification or labelling (ecologic cropping, organic wine, etc.). Sixteen percent of wineries have calculated their carbon footprint or have been subjected to energy audits. These data are consistent with the resources that the wineries in the sample assigned to environmental management (Figure 4). It should be noted that, almost half of the wineries did not have internal resources assigned to it.

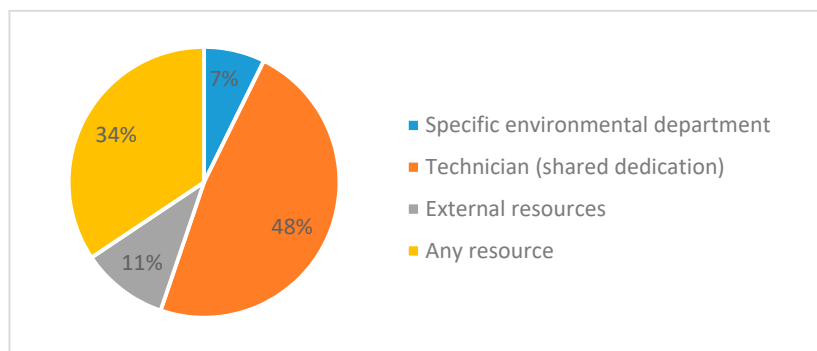


Figure 4. Resources that wineries in the sample assigned to environmental management.

3.1.3. Attitudes on Climate Change

The wineries seemed highly aware of the climate change problem, with an average rating of 7.83 points about the statement "The climate has changed." Similarly, the willingness of sampled wineries to decrease their CO₂ emissions presented an average of 7.83. Despite the limited use of personnel specialized in environmental management, the wineries had already adopted several measures of energy efficiency and general climate change mitigation (Table 5).

Table 5. Energy efficiency and mitigation measures adopted by wineries in the sample.

Climate Change Mitigation Measure	Percentage (%)
Recycling	93
Efficient consumption management	69
Improve thermal insulation	64
Purchase low consumption equipment	51
Reduce weight of packaging	44
New types of containers	35
Estimation and reduction of emissions	15
Other	13

The vineyards' average commitment level to adapting to climate change was high at 7.12, and 50% of the companies had a commitment level above 8. The measures of climate change adaptation that they carried out are shown in Table 6.

Table 6. Climate change adaptation measures adopted by wineries in the sample.

Climate Change Adaptation Measure	Percentage (%)
Advance the vintage date	47
Introduce or increase irrigation	28
Vegetal ground cover	25
Introduce new grape varieties	21
Transfer to higher altitude vineyards	21
Change the architecture of the vineyard	13
Other	4

3.1.4. Renewable Energy: Use and Attitude

The declared use of renewable energy did not represent more than 10% of winery consumption, in any case. The three most common renewable energy types are biomass (11%), photovoltaic power (11%), and solar thermal power (9.3%). Regarding the vineyards, the use of renewables was very limited. Only 5% of vineyards used them, of which 50% used photovoltaics for pumping and 50% produce biomass. For instance, the exploitation of vineyard biomass was very limited (Figure 5).

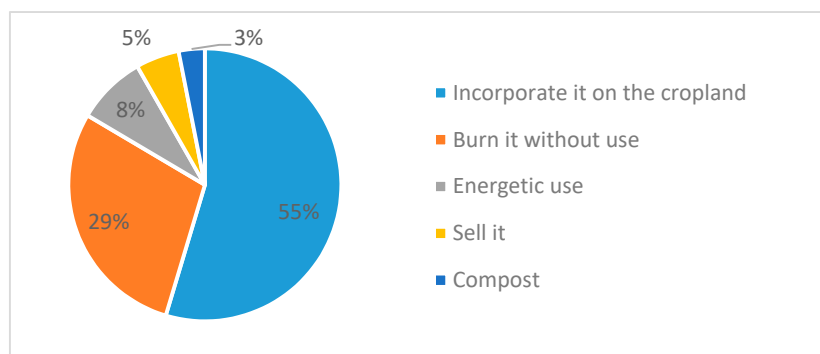


Figure 5. Destination of vineyard pruning waste.

Despite the low level of use of renewables, the wineries were convinced of the need to use them, with an average score of 7.28, and 50% of wineries rated it with more than 8 points. This gap is likely related to the wineries rating the investment involved in implementing renewable energy as high, with 8.33 points, on average. They considered that operating and maintenance costs were lower, and they rated them, on average 5.5 and 5.4, respectively. The aspects that wineries believed favored the adoption of renewable energy, are shown in Table 7.

Table 7. Aspects that favor the adoption of renewables.

Aspect Favoring the Adoption of Renewables	Mean	Median
Environmental sustainability	8.60	8
Impact on image	7.84	8
Reliability	7.24	7
Existence of grants	7.12	7

3.1.5. Use of Conventional Energy

Increased electricity costs have motivated wineries to check their electricity bills. Of the wineries in the sample, 62.7% reduced their reactive power and 66.7% reduced their contracted power. The wineries were asked about their heating and air-conditioning systems; 50% had a heating system and 67% had one or more air-conditioners.

Regarding the vineyards, energy consumption takes place in pumping for irrigation, fed by the power grid or diesel generators. Tractors, grape harvesters, and personnel transport vehicles are fed in all cases with diesel. The average consumption of diesel in the vineyards was € 14,092, although with large deviations; 50% of the vineyards had consumption less than € 5000, of which 82.7% corresponded to agricultural machinery and 7.3% to irrigation pumping, on average.

3.2. Descriptive Statistics of the Variables

Table 8 shows, for the sample of wineries, the mean values and standard deviations of the variables described in Section 2.3.

Table 8. Descriptive statistics of the variables.

Variable	Mean	Standard Deviation
Convinced use	7.28	2.57
Investment	8.33	1.29
Operational cost	5.48	2.41
Maintenance cost	5.44	2.30
Reliability	7.24	2.19
Sustainability	8.57	1.32
Grants	7.12	2.43
Image	7.84	1.80

3.3. Determinant Factors

With the information provided by the respondent wineries, the multivariate statistical technique of factor analysis was applied. A set of indicators was constructed to describe the determinant factors, which influence the implementation of renewable energy. Principal components and orthogonal varimax rotation, were used to obtain the main four factors explaining 77.4% of the total variability. Table 9 presents the rotated components matrix, with correlations between factors and original variables.

Table 9. Rotated components matrix.

	Cost Factor	Conviction Factor	Investment Factor	Sustainability Factor
Operational cost	0.943	–	–	–
Maintenance cost	0.936	–	–	–
Convinced use	–	0.863	–	–
Image	–	0.797	–	–
Grants	–	–	0.840	–
Investment	–	–	0.728	–
Reliability	–	–	–	0.825
Sustainability	–	–	–	0.785

From this matrix, it is possible to name and interpret each factor as follows:

- **Cost factor:** This factor is positively related to operational and maintenance costs. That is, if a winery considers that the costs associated with renewable energy are high, then it has a high score in the cost factor.
- **Conviction factor:** This factor is positively related to the conviction of using renewable energy and reputational image. That is, if a winery is convinced of using renewables and gives great importance to perceived image, then it has a high score in the conviction factor.
- **Investment factor:** This factor is positively related to investment. That is, if a winery considers the investment in renewable energy to be too high, then it has a high score in the investment factor. Therefore, it probably prefers to adopt other measures to mitigate climate change. This factor also includes companies with high scores in the subsidies variable, which means that companies would see subsidies as a way to compensate for the high amount of investment.
- **Sustainability factor:** This factor is positively related to motivations that can lead a winery to adopt renewable energy, such as the importance of sustainability and reliability. That is, if a winery considers that sustainability and reliability are decisive for implementing renewables, then it has a high score in the motivation factor.

3.4. Types of Wineries

A multivariate cluster analysis technique was used on the four indicators to classify the wineries. This procedure is an exploration tool, designed to discover natural groupings of a set of data. It

allows categorical and continuous variables to be treated jointly, using the likelihood provided by the probability distribution between the variables as a measure of distance between two individuals. A normal distribution is assumed for continuous variables, and multinomial distributions for categorical variables. The first stage consists of a pre-classification that sequentially builds a tree, where its nodes represent groups. The previous solution is refined in the second stage through an agglomerative hierarchical procedure. The final algorithm automatically selects the number of clusters, using a model selection criterion for different grouping solutions. In our case, the four indicators were continuous variables and the selection criteria used was the Bayesian information criterion (BIC), implemented with SPSS 22 software. This analysis identified three groups (Figures 6 and 7), including 40%, 40% and 20% of the wineries. The characteristics are explained and discussed in the next section.



Figure 6. Winery groups.

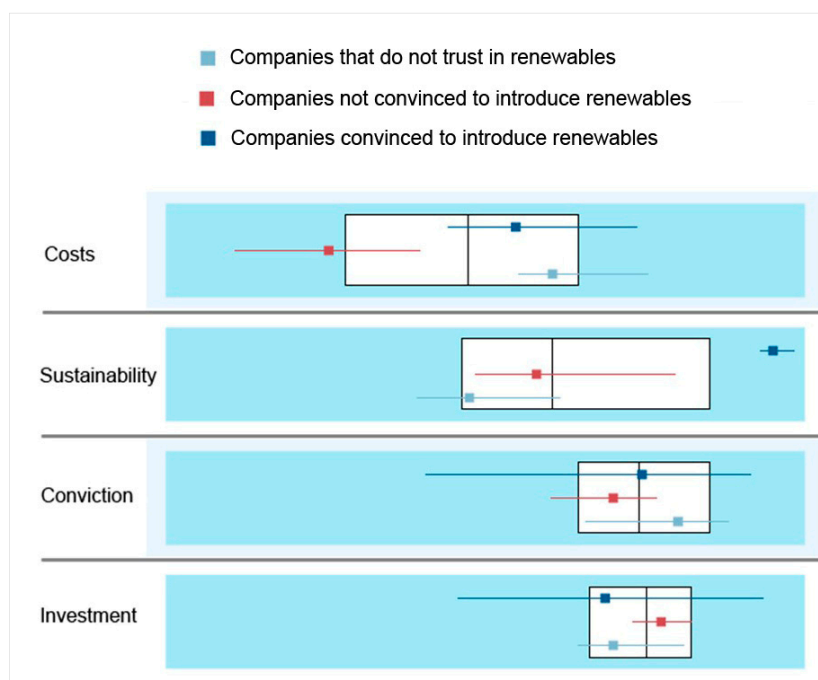


Figure 7. Comparison among winery groups.

4. Discussion

The three groups of wineries presented characteristics that allowed us to interpret different dispositions of companies in the wine sector to incorporate renewable energy:

1. **Companies that do not trust renewable energy.** This group comprised 40% of the sample. These companies were not convinced of the environmental importance of introducing renewable energy.

They did not believe that renewables were sufficiently developed to be a reliable energy supply. The main driver they considered for incorporating them, is the impact on image and reputation. They were not worried about the investment, and consequently they did not feel the need to establish a subsidy system.

2. **Companies that are not convinced to introduce renewable energy.** This group comprised 40% of the sample. These companies were not convinced to introduce renewable energy. Neither environmental nor reputation points were sufficient to motivate them. They did not consider that in their case, starting up renewable energy will give them an image improvement or significant CO₂ savings. They considered that the investment costs were high, and the environmental improvement to their image would not compensate them. However, they were not worried about the maintenance costs.
3. **Companies that are convinced to introduce renewable energy.** This group comprised 20% of the sample. These companies wanted to reduce CO₂ emissions. Their interest in sustainability was the main driver, above factors such as obtaining a clean company image. For these companies, reliable supply and environmental improvement were the most outstanding aspects. They were not worried about the investment costs. In contrast, they considered that the maintenance costs are high.

Beyond the existence of a wide spectrum of individual cases, the three groups had characteristics that agree with practical experience. A large number of wineries (group 1) are not yet considering investing in renewables, although they do not rule out doing so in the future. This attitude may be related to the novelty of renewable energy technologies. In the case of Spain, the administrative obstacles and lack of public promotion in recent years, may also play against it. Another large number of wineries (group 2), seemed to be completely absorbed by the core of their business, without worrying about the sustainability of their input, and especially without knowing the large share of energy in the carbon footprint of their activity. Some wineries, not a majority, but a considerable number, are already willing to make the investment to incorporate renewable energy.

The results obtained may indicate some ways to encourage the transition to renewable energy in the wine sector.

First, the number of companies that are already willing to incorporate renewable energy (group 3) is sufficient to initiate this transition in the sector. However, that market has not yet been activated in significant quantity. It is important to keep in mind that companies in the wine sector do not know about energy technologies. For instance, the belief of many companies that the costs of operation and maintenance of renewables are high is completely wrong. This lack of information is likely related to the fact that 34% of wineries in the sample did not assign resources to environmental management, as indicated in Section 3.1.2. Increased information and technical and economic offers for the decision-makers of the sector, would probably increase the demand for renewable facilities. Nevertheless, the possible existence of subsidies, by itself, is not enough motivation. Even for the most willing group, the largest investment required to incorporate renewables represents a disadvantage, compared to traditional energy options. For this reason, an excellent measure would be to facilitate access to financing.

Second, a large group of companies believed that it was not yet time to switch to renewable energy (group 1). This perception is no longer correct, since renewable energy technologies have reached a sufficient degree of maturity. However, many stakeholders still do not know their feasibility. Therefore, the same measure proposed for the first group is necessary here, that is, an increase in information and technical and economic offers.

Finally, a big group of wineries were not interested in renewables (group 2). This is not strange, given the novelty of this technology and its distance from the core of the wineries' activities. Again, the limited resources dedicated to environmental management by the wineries may be behind this lack of interest. It is reasonable to expect that future introduction of renewables in the sector, led by companies in group 3 and supported by group 1, will modify the perceptions of this group. In addition,

the foreseeable environmental and energy policy, as well as the evolution of the market, will end up pushing the transition, even in the absence of other convictions.

The results obtained were in agreement with other studies related to the incorporation of renewable energy [40]. It has been identified that the highest economic barrier is the high initial investment. In contrast, a lack of subsidies is the lowest economic barrier. The lack of a sufficient market base and of political commitment, have also been reported as high barriers.

Regarding the wine sector, some studies [31,32,34,41] have shown limited adoption of environmental innovations, although with some regional differences. This coincides with the low adoption of renewable energy observed by the present study. However, many Spanish wineries have incorporated other mitigation practices (different to renewable energy) to increase sustainability, as shown in Table 5.

To introduce sustainability in the wine sector, one study [42] shows the successful case of the Sustainable Winegrowing New Zealand program [43]. The process shown is interesting, although it differs from the Spanish case, because it belongs to the new world, where, in its export market, sustainability of products is a very valued factor. In addition, the energy standard of this program is based on reducing the amount of energy used, whilst the present study focused on substituting renewable energy sources. Although Spanish wineries export a large part of their production, in the survey they indicated that only part of their market demands wines with an image of sustainability, and in any case, this was not their competitive advantage. Consequently, it is not expected that market pressure will push the Spanish wine sector toward sustainability in the short term, and generally. Other studies [33,35] agree with this assessment, especially in the old world.

In this study, an important mismatch was found between the favorable perception of decision-makers regarding renewable energy, and its actual implementation. According to other studies [25], the social norms perceived by decision-makers could be more directly associated with their decisions, than the managers' attitudes themselves. In fact, the positions held during the last decade by the government and the energy companies in Spain, and the situation of paralysis, were generally regarded as negative [44]. This has caused a climate of doubt about the opportunity to change toward renewable energy sources. Moreover, sociopolitical and community acceptance are important to understand the apparent contradictions, between general public support for renewable energy and the difficulty in realizing specific projects [45]. For the aforementioned reasons, the attitude of waiting for better times before investing in renewable energy can be widespread, especially in the wineries of group 1. Nevertheless, information and perceptions are modifiable, adding more weight to the likelihood of adoption [46]. For this purpose, carefully tailored information on the use of renewables for wineries should be made available to winemakers. Regarding the dissemination of innovations [23], information is the key.

5. Conclusions

The wine industry consumes significant amounts of energy. Climate change affects the winemaking process severely, especially in the vineyard. In addition, both the commercial interest and the social responsibility of the companies point the same way. For these reasons, beyond adaptation measures, it is essential that the sector actively contributes to mitigation. Incorporating renewable energies in their processes can considerably reduce the CO₂ emissions associated with the activity and the product. The technical and economic feasibility of this change has been demonstrated. However, implementation depends on the stakeholders. In addition, the attitudes of the wineries are far from unanimous in that direction.

Although the study was carried out with a representative sample of Spanish wineries, it would have been desirable to work with a larger sample. However, it was difficult to obtain a large number of responses to the questionnaire. With the available data, the confidence level was 94%, with an error rate of 10%.

This work identified the existence of three groups of Spanish wineries, with different attitudes. First, 20% of Spanish wineries are willing to incorporate renewable energy. Second, 40% are favorable, but do not believe that it is time to invest in it. Finally, 40% of wineries are not interested in incorporating renewables. Despite the favorable attitude of a significant group of wineries, it must be considered that the willingness to implement renewable energy is not enough, nor is it the only factor for its real implementation. The results suggest two main measures to encourage an energy transition in the Spanish wine sector: (i) Increasing the information provided to decision-makers in the sector, including technical and economic offers; and (ii) Facilitating access to financing.

Regarding future research, a study of the three identified groups can be addressed through representative case studies. Moreover, statistical models could be proposed and tested to determine which characteristics of the wineries are related to their implementation of renewable energy. A comparison of the Spanish case with the results obtained in other regions, both in the old world and in the new world, could be interesting. In the same way, similar studies could be carried out on the incorporation of renewable energy in other sectors, especially in agricultural farms.

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