

EXCELLENCE HUBS: EXCELLENCE/1216/0279
EcoWinery: Eco-innovation for the production of low
environmental footprint wine



Sustainable wine best practices manual – Deliverable for the
WP5 of the project EcoWinery

Prepared by CUT (HO) with the support from OUC (PA2)

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1. EcoWinery TEAM



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2. ABOUT THE PROJECT

Cyprus has a history of more than 5.500 years in wine production with vineyards shaping the rural landscape of the island. However, wine imports have progressively captured two-thirds of the share of the local market, outcompeting local SMEs that

need to create a unique identity for their product.



ECO-WINERY aimed at promoting eco-innovation in vineyards and wineries to enable local SMEs to differentiate their wines based on the inherently low environmental impact and

significance for the cultural heritage of the island. The project brought together four respected institutions and an SME (Figure 1) representing a diverse range of complementary expertise. The consortium established an EXCELLENCE HUB to determine the product environmental footprint of wine, in line with recent EU recommendations. ECO-WINERY delivered user-friendly tools for the determination of the environmental footprint of wine in line with Cypriot consumer concerns and explored best practices for lowering the environmental footprint of wine.

The project delivered novel and high-quality knowledge on Product Environmental Footprint determination, biodiversity conservation and carbon sequestration in vineyards, towards low footprint wine production, zero waste economy and climate change mitigation.

Networking activities with leading organizations and enterprises from other countries promoted the flow of information and accelerated pioneering progress in the field.



Figure 1. Photos from the SME Nicolaides Boutique Winery

3. THE AIM OF THIS MANUAL

The manual translates the results of Eco-Winery WPs into concrete recommendations to help farmers and wineries with decision-making in reducing the product environmental footprint in vineyards and winemaking. The manual provides recommendations for best practices in vineyard and winery management which will reconcile production with conservation and sustainable use.

The design of the recommendations is based on existing schemes that have proven success in improving management practices towards sustainability and providing a

marketing advantage (e.g. the Italian Viva Sustainable Wine - <http://www.viticolturasostenibile.org>, the Lodi Rules Sustainable Winegrowing in California - <http://www.lodigrowers.com/lodirules/certification/>, the Biodiversity and Wine Initiative in South Africa - <http://www.swsa.co.za/biodiversity.htm>). However, the current manual focuses more on simplicity, to enable its use and application by small-scale farmers and the SME wineries that form the backbone of wine production in Cyprus. The Manual in combination with the tools and the research conducted in the project can serve as the basis for the development of a voluntary certification scheme in the future through the adoption of a scoring approach, where management practices less disruptive to the environment receive high points, whereas practices considered damaging receive low points.

3.1. How to use the manual

The current Manual has two main parts: a) Vineyard practices and characteristics and b) Winery practices. The Manual accompanies the PEF Tool developed within the framework of Ecowinery (D15), and all the practices/characteristics available as options within the Tool are discussed in the current Manual. Tables 2 and 6 show an overview of the impact of vineyard/winery management practices and features on PEF, with a description for each practice and feature options. The practice options follow the format of the PEF Tool (D15), although some options are not available in the Tool because they were not applied in the study vineyards of the project are discussed here.

4. VINEYARD MANAGEMENT AND CHARACTERISTICS

An overview of the contribution of the different practices in the vineyard to the wine PEF is provided in Table 2, with a discussion of each practice in sections 4.1 through 4.6.

4.1. Soil Management (tillage frequency)

Carbon Footprint (CF) : Soil tillage favours organic matter decomposition, therefore C emissions from the soil, especially when it is frequently applied (Haddaway et al., 2017). Reduced or no-tillage can lead to C sequestration in the soil (Fig. 2). When tillage in vineyards is practised two or more times per year, this increases the GHG emissions from viticulture (e.g., use of machinery and diesel consumption) (Litskas et al., 2017, 2020) substantially. No-tillage has the maximum benefits to GHG emissions mitigation as no machinery or fuel is used and C decomposition in the soil is slower compared to reduced or more frequent tillage. Tillage can also lead to soil erosion.



Figure 2. Tillage (top) and no-tillage (bottom) in bush vines. Photo EcoWinery

Water Footprint (WF) : No-tillage has a neutral effect on the water footprint (e.g., L of water per kg of grapes produced). Reduced tillage, especially in rainfed vineyards can improve water storage in the soil. Frequent soil tillage can lead to water loss due to increased evaporation from the soil.

Nitrogen (terrestrial eutrophication) : No-tillage can lead to N loss as the fertilizers are applied on the surface of the vineyard and increased volatilization and runoff could occur (Liu et al., 2015). Frequent tillage could also lead to N loss due to increased N₂O release. Reduced tillage (once per year for fertilizer incorporation) could reduce losses due to volatilization and increase vine N uptake.

Biodiversity : No-tillage has a positive effect on target groups such as grass and flowering plants, pollinators (wild bees, social bees, butterflies, wasps), birds and reptiles while it increases grass and flowering density and diversity providing more food and refuges for pollinators, invertebrates, birds, and reptiles (Figs. 3-5). However, it should be taken into consideration that long-term no-tillage management could lead to plant competition and dominance of few species resulting in lower plant density and diversity. Tillage once per year does not have any strong negative effect if it is applied in periods of low pollinator and other fauna mobility. Moreover, in some cases, tillage creates favourable conditions for new germinations of annual species (Gago et al., 2007). Moreover, reduced tillage in vineyards could provide more food resources and refuges in target groups such as reptiles. Mosaic of heterogeneous vegetation patches (patches of bare ground and vegetation interrow) provides beneficial conditions for taxa, which benefit from bare ground, like ground-foraging bird species (Schaub et al., 2010) or wild bees (Potts et al., 2016). On the other hand, conventional and frequent tillage of two or more times per growing season could have a negative effect in all target groups by decreasing plant density and diversity, food and refuges (pollinators, reptiles and birds) and nesting sites. In general, vineyards are considered as perennial systems of a low disturbance where a decrease in disturbance reduces environmental heterogeneity and diversity of flora and fauna (Bruggisser et al., 2010).



Figure 3. Conventional and frequent tillage in vineyards of EcoWinery selected for biodiversity monitoring.



Figure 4. Vegetation strips between vines (up) and no-tillage management with flowering plants such as *Hypericum triquetifolium* (middle and down) in vineyards selected for biodiversity monitoring during the EcoWinery project.



Figure 5. Nesting sites of ground-foraging wild bees (up) and of the endemic reptile subspecies *Stellagama stellio cypriaca* (down) in vineyards of EcoWinery project.

Yield: Tillage once per year could increase water infiltration to the soil and incorporate fertilizers, making nutrients available for vine development. Therefore, it could have a higher benefit for yield, in comparison to no-tillage (Chrysargyris et al., 2018, 2020) and frequent tillage. Frequent tillage could increase water loss because of higher evaporation.

4.2. Synthetic fertilizers

Carbon Footprint (CF) : The application of synthetic fertilizers increases N_2O emissions from soils (Hillier et al., 2011; Christodoulou et al., 2019). In addition, the production of synthetic fertilizers leads to higher GHG emissions (Hillier et al., 2011) (Figure 6). Emphasis should be given to N_2O mitigation, as it is a powerful GHG (Figure 7). Selection of fertilizers could be done according to their emission factors (see Figure 8). Fertilizer application in general increases the PEF for wine (Table 2). However, because no fertilizer addition decreases grape yield, the consensus option is to apply fertilizers once per year or less often.

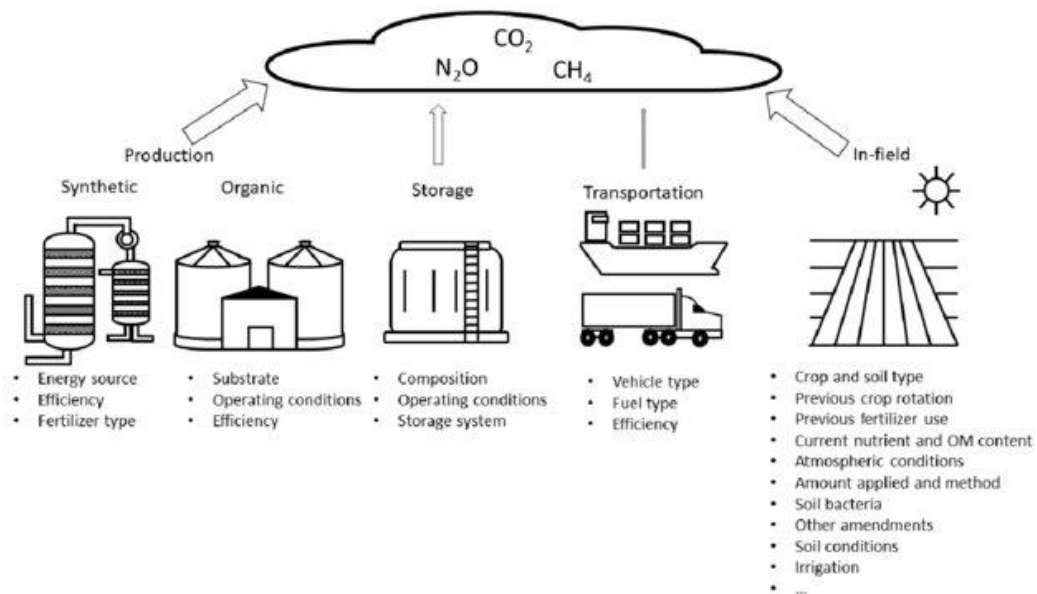


Figure 6. Life Cycle of fertilizers and emissions Source: (Walling and Vaneeckhaute, 2020).

Water Footprint (WF) : The application of synthetic fertilizers affects water uptake and vine growth. Yet, it is difficult to assess the effect of fertilizers application on water footprint. If the life cycle of fertilizers is taken into account, their production consumes water. Therefore, the WF of fertilizer application is higher than no application.

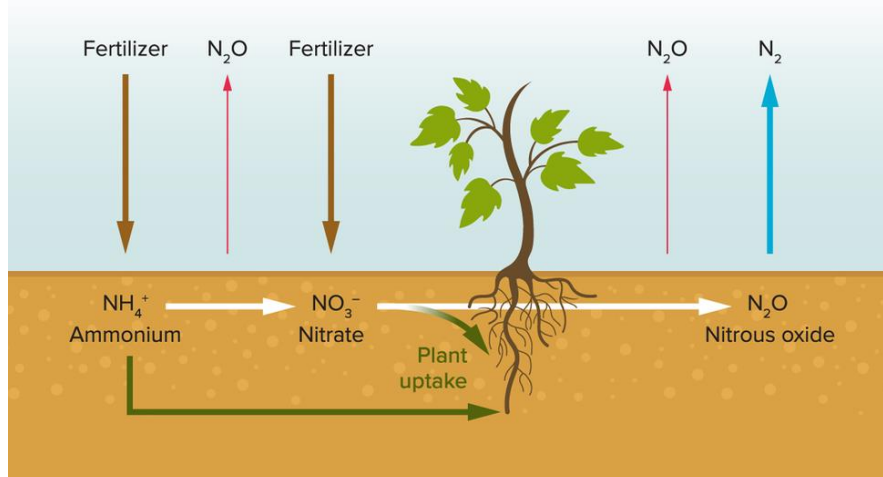


Figure 7. N transformations in the soil. Source: BBC FUTURE.

Nitrogen (terrestrial eutrophication): Fertilizers overuse could enhance terrestrial eutrophication (e.g., excess of N in the environment). Regarding this indicator, no use is the best option for elimination of N excess.

Biodiversity: Low and intermediate levels of synthetic fertilizers might have no substantial direct effects on biodiversity, with the exception of plants. However, excessive fertilization, or any change from background levels in the region could alter

changes in the composition of the plant community (Boch et al., 2021a) as well as in the chemical composition of flower pollen and nectar which can affect visitation of pollinator species that are attracted by flowers with specific chemical contents (Ramos et al., 2018).

Yield : No fertilizers use could have a significant impact on yield, reducing the number of grapes and affecting the health status of vines (e.g., deficiencies). Over-application of fertilizers results in losses, as the plant cannot uptake the surplus amount of nutrients.

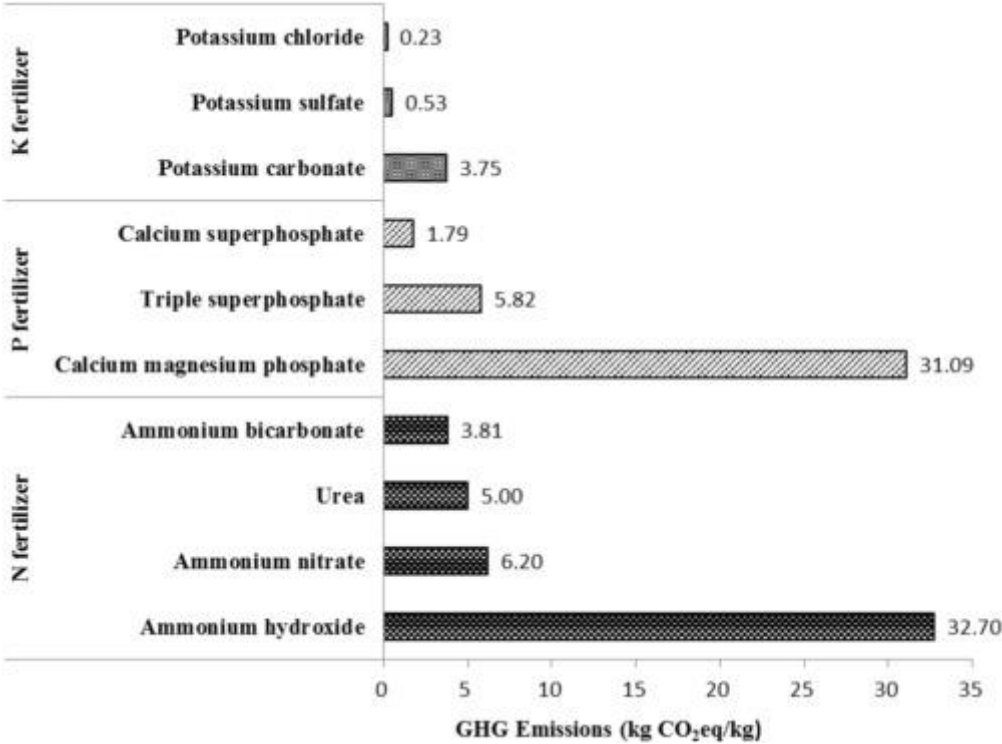


Figure 8. Emission factors for the production of different fertilizer types (CO₂-eq/kg of fertilizer). Source (Wang et al., 2017).

4.3. Organic fertilizers

Carbon Footprint (CF) : No application of organic fertilizers harms C storage and soil organic matter which is a key indicator for soil function (Ioannidou et al., 2022). On the other hand, the overapplication of organic material could be linked to negative environmental impacts (e.g., nutrients leaching, GHG emissions). Application of organic fertilizers (e.g., sheep/goats manure) (Figure 9) once a year supports C farming and plant nutrition.

Water Footprint (WF) : Organic fertilizers application, especially in irrigated vineyards could reduce the water footprint as water is stored more efficiently in the root zone (Ioannidou et al., 2022).

Nitrogen (terrestrial eutrophication): Overapplication of organic fertilizers could lead to increased N loss in the environment (Whittaker and Shield, 2016).

Biodiversity: The use of organic fertilizers could likely have the same effects as synthetic fertilizers (see Section 5.2), although in this case potentially negative effects from low levels of application are expected to be lower than for synthetic fertilizers.

Yield: The application of organic fertilizers supports plant nutrition but the vine grower should consider that nutrient release is much slower than in the case of using synthetic fertilizers (Garzón et al., 2011).



Figure 9. Application of organic fertilizer (80/20 w/w manure and winery waste) in the EcoWinery experimental vineyard.

4.4. Irrigation

Carbon Footprint (CF) : The GHG emissions in the case of irrigated vines are related to the manufacturing of the irrigation network and energy use (e.g., electricity, diesel) for pumping and/or water distribution (Litskas et al., 2021).

Water Footprint (WF): Irrigation increases the water footprint in vines.

Nitrogen (terrestrial eutrophication): Water overapplication, in combination with the use of synthetic fertilizers could lead to an increase in N presence in the terrestrial and aquatic environment.

Biodiversity : The effect of irrigated vs rainfed vineyards on biodiversity should be considered in combination with other management practices such as fertilization and vegetation management (Boch et al., 2021b). Irrigation could promote an increase in plant density and hence provides more food resources and refuges for other target

groups, but simultaneously may increase the incidence of pest species that prefer vigorously growing vines (Winter et al., 2018). The overwhelming majority of vineyards included in the current work are non-irrigated (see Fig. 10 for a few exceptions), so no assessment of the effects of irrigation on biodiversity could be made. Therefore the practice was not included in the current version of the biodiversity component of the PEF Tool.

Yield : Irrigation generally leads to an increase in the yield of grapes provided that all the other parameters (e.g., nutrients, disease) are optimal (Chrysargyris et al., 2018, 2020). In the case of Cypriot indigenous varieties, irrigation could even double grape production. Typically, there is no irrigation water available or extensive irrigation networks (e.g., community level). In addition, irrigation of vineyards in the PGO Commandaria region is generally prohibited, as the characteristics of the sweet desert Commandaria wine depend on the rainfed nature of vine growing in the region.



Figure 10. Irrigated vineyards selected for biodiversity monitoring during EcoWinery project.

4.5. Pest and disease management

Carbon Footprint (CF): The application of plant protection products PPPs (herbicides, insecticides, fungicides) leads to GHG emissions (Hillier et al., 2011; Litskas et al., 2017). The emissions related to plant protection were about 5% in a study on grapes in Cyprus (Figure 11). Averages of around 14.7, 18.4, 20.9, and 28.1 kg CO₂-eq/application per hectare for fungicide, growth regulator, herbicide and insecticide respectively, are reported in Hillier et al. (2011). These values are related to the active

ingredient manufacturing and application in the field, using spraying machinery. Targeted spaying (e.g., focusing on infected areas in the vineyard) reduces the CF due to pest management. Certified organic vineyards have lower CF (not only due to plant protection) than high inputs conventional vineyards. However, increased fuel use for tillage and weed management could increase the CF of organic grapes (Litskas et al., 2020).

Water Footprint (WF): There is no link between pesticides application and water footprint (L of water use per kg of product). A healthy vine, which may be the result of pesticides use produces more grapes but water use is also higher. Therefore, it is difficult to assess the effect of pest management on the water footprint.

Nitrogen (terrestrial eutrophication): There are no data in the literature to link pest management in vineyards to eutrophication. We expect a neutral effect as pesticides are not known to contain significant amounts of N.

Biodiversity: Pest and disease management has different effects on the taxa of the different trophic levels (Fig. 17). An analysis of the effects of different pesticide classes follows below.

Insecticides: Besides pests, intensive use of insecticides can also negatively affect beneficial insects (natural enemies, predators) for the cultivation as well as pollinators. This impact could increase if applications are carried out at periods other than early morning or late afternoon when flights of pollinators are peaking. (Figure 12). In addition, many insecticides are harmful to reptiles and birds, and therefore intensive applications are expected to negatively affect biodiversity conservation. Of course, the type of insecticide used is very important, as different insecticide classes and active ingredients have different toxicity to non-target species. However, at the current version of the PEF Tool the negative effects of biodiversity increase with increasing application frequency without dependence on the product used. The next versions of the PEF Tool for biodiversity can estimate different impacts depending on the product used.

Fungicides: The negative effects of fungicides on the species groups included in the current version of the PEF Tool Fungicides increase with application frequency, but at

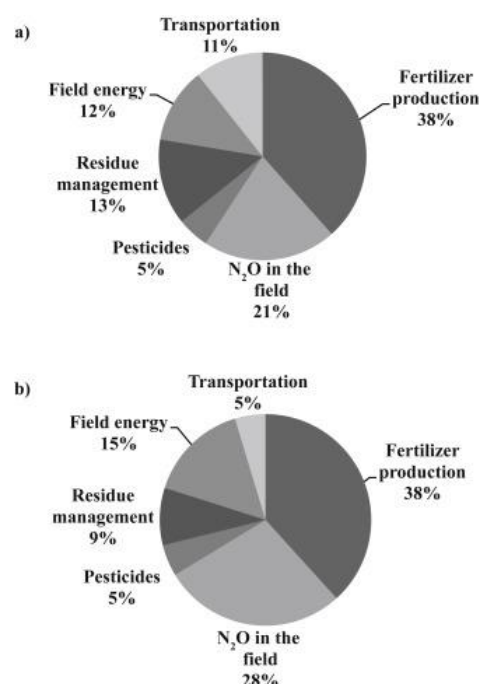


Figure 11. Contribution of management practices to the PCF of grape production for (a) the local variety Xynisteri, (b) the introduced Cabernet Sauvignon. Litskas et al. (2017).

a milder slope than for insecticides. As for insecticides, an exact assessment of fungicide use on species groups requires information on the product used, and its potential effects on different species, but such information is currently unavailable for the majority of species present in vineyards.

Herbicides: Intensive use of herbicides (3 or more applications per growing season) could harm plant density, diversity, and composition as well as in plant growth and the number of flowering buds. Several side effects on pollinators, birds as well as reptiles are being expected due to the degradation of their habitats (Puig-Montserrat et al., 2017; Schmitt et al., 2008; Feber et al., 2007).

Reducing the number of applications of PPPs (2 or fewer applications per year) could moderate the adverse consequences on target groups while avoiding the use of chemicals will contribute to the conservation and enhancement of biodiversity.

Yield: The application of plant protection products in vines could enhance plant health, therefore increasing the yield. Overapplication (e.g., sulfur) can lead to tissue damage. Even though increasing the application frequency of pesticides might not harm yield directly, it does increase the financial cost for farmer unnecessarily.



Figure 12. Endemic butterfly *Hipparchia syriaca cypriaca*, wild bee *Andrena* sp., bush-cricket *Tylopsis lilifolia* and the endemic lizard *Phoenicolacerta troodica* in EcoWinery vineyards.

4.6. Landscape features

The current version of the tool includes three types of landscape features: The proportion of (semi-) natural vegetation in the plot, the linear length of stonewalls or rockpiles with a height greater than 50 cm per decare, as well as the number of cultivated tree species per decare in the vineyard. The effect of the three types of landscape features on wine PEF is discussed together in the following paragraphs.

Carbon Footprint (CF): Percentage of field area covered by wild vegetation and number of cultivated species in the vineyard and field margins affect GHG emissions. Wild vegetation and cultivated species uptake CO₂ from the atmosphere and enhance C storage in the soil as they deposit litter (Figure 13). The total length of stonewalls or stone piles is not directly linked in the literature to GHG emissions. The percentage classes included in the current work were selected to represent ranges observed in the 36 vineyards of the Ecowinery project, where only a few vineyards fell in the 9% or less class. The specification of classes boundaries, however, is open to debate, with a reasonable minimum limit being the 10% landscape features set out in the EU Biodiversity Strategy to 2030.

Water Footprint (WF): When wild vegetation or cultivated trees are present in the vineyard, water footprint might increase, especially in the case of irrigated vines. Vegetation in the field margins does not affect the water footprint of grapes. Stone walls, protect soil and retain soil moisture. However, their presence could not be linked in the literature to increased or decreased WF.

Nitrogen (terrestrial eutrophication): Wild vegetation in the field and the margins can protect natural habitats against the overapplication of fertilizers (Table 1).

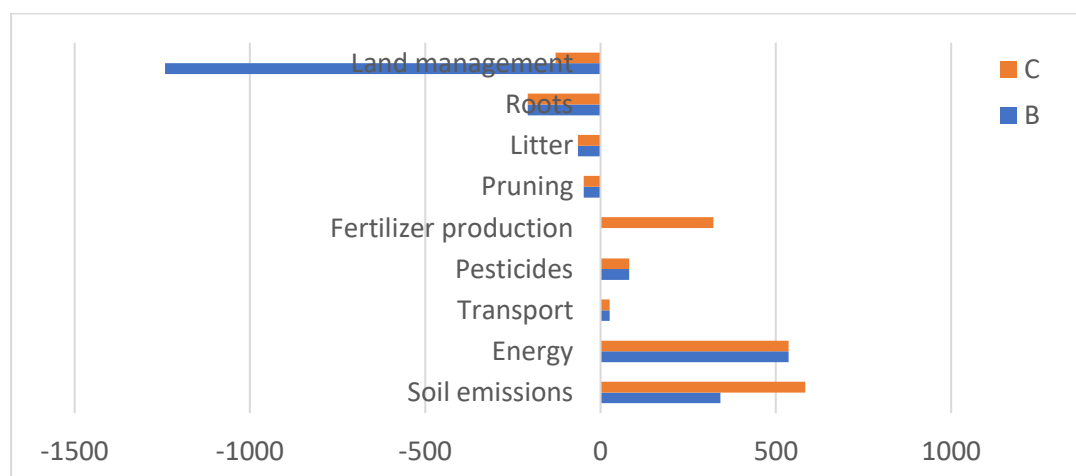


Figure 13. Contribution of parameters and management practices to the CF; data in kg CO₂-eq/ha/yr. B, C are treatments in the experimental vineyard of EcoWinery project. In the case of treatment C, where >2 times per year tillage was applied native vegetation in the field margins contributed to -128 kg CO₂-eq/ha/yr. In A, B reduced tillage is also practised.

Table 1. Major functions of field margins in agroecosystems. From Marshall and Moonen (2002).

Function	Role
Agronomy	Land ownership, stock fencing, shelter, windbreak, weed and pest control, game and wood
Environment	Pollution control, eutrophication, pesticides, erosion, snow and water flow, and siltation
Nature conservation	Species refugia, biodiversity, habitat, feeding, breeding, corridor and movement
Recreation and rural development	Access, walking, driving, hunting, tourism, aesthetics, culture and heritage

Biodiversity: Landscape features (Figures 14-19) such as natural, semi-natural vegetation, terraces, hedgerows, stone walls, brush and stone piles are important parts of agricultural ecosystems providing food resources, refuges, nesting places, breeding sites as well as various ecosystems services contributing to a balanced agroecosystem (Pulleman, 2012; Paiola et al., 2020). Moreover, one of the goals of the EU Biodiversity Strategy is 10% of farmland to be under landscape features by 2030.

Field margin vegetation: Grasses, vascular plants, shrubs, and trees (cultivated and wild) contribute to the conservation of biodiversity providing food resources, refuges, nesting places, breeding sites to pollinators, reptiles and birds. Moreover, field margin could serve as a source of beneficial insects and hence their presence is also important for pest control. Moreover, there is a positive correlation between biodiversity (number of species as well as the number of individuals per species) and number and/or density of field margin vegetation.

Stonewalls: Except for their importance in preventing soil erosion, stonewalls are excellent refuges and nesting sites for reptiles while sometimes accommodating plant species important for pollinators and birds. The larger in length the greater their contribution to biodiversity conservation.

Yield: There is no clear evidence on the effect of landscape features on grape production.

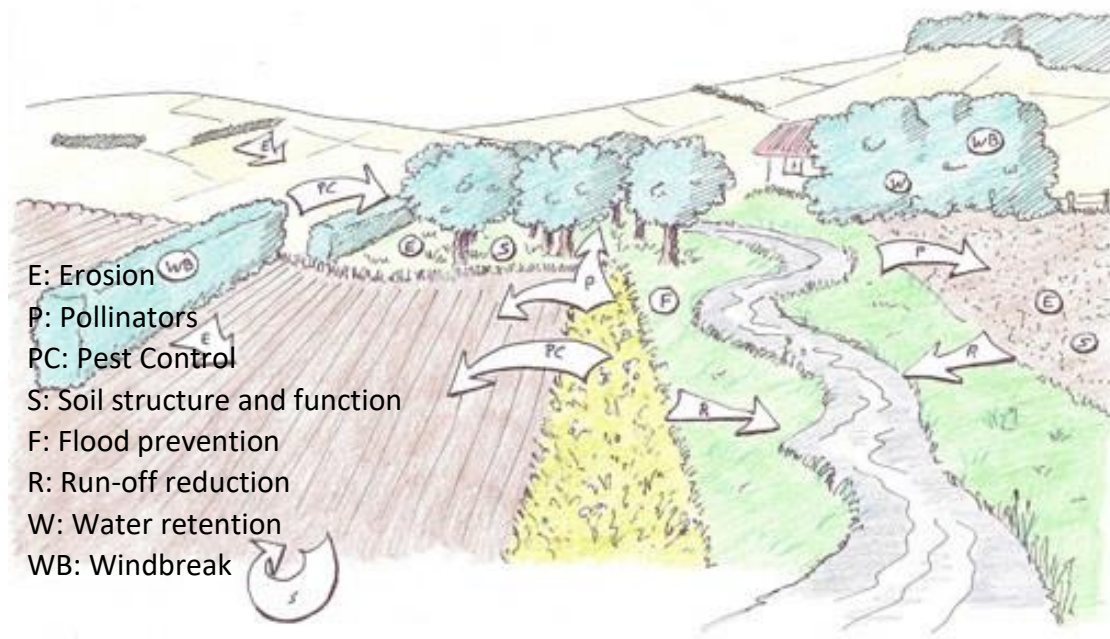


Figure 14. Functional agrobiodiversity and provision of multiple ecosystem services in an agricultural landscape (Drawing: Ben Delbaere).



Figure 15. Field margin vegetation in EcoWinery vineyards. Hedgerow and terraces diversity in vascular plants, shrubs and trees.



Figure 16. Field margin vegetation in EcoWinery vineyards. A more uniform hedgerow in flora diversity with the dominance of the cultivated species *Olea europea*.



Figure 17. Field margin vegetation in EcoWinery vineyards. Low diversity in floral species richness and abundance.



Figure 18. Stonewalls in hedgerows and terraces of vineyards selected in the frame of the EcoWinery project.





Figure 19. Rock piles in the centre of a vineyard provide refuge and nesting place in reptiles and insects (up) and a birds nest in the shrubby plant *Cistus creticus* found in the hedgerow of a vineyard (down).

Table 2. Evaluation of management practices impacts on the PEF and yield.

Management practice / Feature	Practice	CF	WF	Nitrogen	Biodiversity	Yield / Yield economics	Preferable
Soil tillage	No application						
	Once per year or less						
	Twice per year or more						
Synthetic fertilizers	No application						
	Once per year or less						
	Twice per year or more ¹						
Organic fertilizers	No application						
	Once per year or less						
	Twice per year or more ¹						
Irrigation	No/rainfed						
	Yes						

Management practice / Feature	Practice	CF	WF	Nitrogen	Biodiversity	Yield / Yield economics	Preferable
Insecticides	No application						
	Once per year or less						
	Twice per year or more						
	Three times per year or more						
Fungicides	No application						
	Once per year or less						
	Twice per year or more						
	Three times per year or more						
Herbicides	No application						
	Once per year or less						
	Twice per year or more						
	Three times per year or more						

Management practice / Feature	Practice	CF	WF	Nitrogen	Biodiversity	Yield / Yield economics	Preferable
Percentage of field area covered by wild vegetation	9% or less						
	10-19%						
	20-29%						
	30-39%						
	> 40%						
Cultivated species in the vineyard	0 / decare						
	Up to 0.5 / decare						
	Up to 1 / decare						
	Up to 1.5 / decare						
	More than 1.5 / decare						
Total length of stonewalls or stone piles	0 - 2 m						
	2- 34 m						
	35-64 m						
	65-94 m						

Management practice / Feature	Practice	CF	WF	Nitrogen	Biodiversity	Yield / Yield economics	Preferable
	>=95 m						

Legend

Very good	Good	OK	Neutral	Bad	Very bad

5. WINERY

An overview of the contribution of the different practices in the winery to the wine PEF is provided in Table 6, with a discussion of each practice in sections 5.1 through 5.4.

5.1. Winemaking

5.1.1. Electricity

Carbon Footprint (CF): The environmental footprint of electricity production in Cyprus is presented in Table 3. Electricity is produced by thermal power generation using hydrocarbon energy sources (heavy fuel oil and gasoil) (Figure 20). SME wineries typical electricity consumption is close to 1 kWh/bottle of wine. Typical wine production in Cypriot SME wineries is 20000 – 200000 bottles of wine. Reducing electricity consumption is essential for environmental footprint mitigation. Therefore, annual consumption of <20000 kWh is considered optimal for low PEF wine. This can be achieved by optimizing energy consumption in the winery (e.g., machinery, chiller, building) and/or installing photovoltaic panels for electricity production.

Table 3. Environmental impact (LCA) of 1 kWh electricity produced in Cyprus.

Amount	CF (kg CO ₂ -eq)	WF (m ³)	N (mol)
1 kWh	0.871	0.066	0.0057



Figure 20. Steam units for electricity production, Vassilikos, Limassol.

Water Footprint (WF) : As presented in Table 3, for each kWh consumed in the winery 66 L of water are needed (this is water consumed in the production process; e.g., cooling). The lower the electricity consumption, the lower the WF of winemaking.

Eutrophication (N) : The same, as the WF applies for N released to the environment (Table 3), due to the inputs and processes used for electricity production.

5.1.2. Water use (direct)

Carbon Footprint (CF) : Water source in the winery (e.g., cleaning, washing) could be the community network or pumping from a borehole. In both cases, electricity is typically used, besides the amount of water. In this case, the higher the water use, the higher the GHG emissions (due to pumping, water distribution etc.).

Water Footprint (WF): Based on our data collection, from SME wineries, 1.5 L of water are needed in the winery per bottle of wine. This water is used mainly for cleaning purposes. Therefore, an amount of water consumption of 10-50 m³ / year is considered reasonable for a typical SME winery. Most of the wineries do not have facilities for water recycling, which should further reduce water use and improve environmental performance.

Eutrophication (N): Direct water use in the winery, when treatment facilities are not present, results in wastewater release into the environment. Even though it is difficult to assess N content (different wineries, different effluents), the higher the wastewater production the worse for eutrophication.

5.1.3. Fuel consumption (corporate)

Carbon Footprint (CF): In Table 4, the environmental impact of diesel consumed in a small truck or van, is presented. Optimally, due to the high impact of fuel use, its consumption should be minimized. The lower the fuel use, the lower the GHG emissions (CF). The life cycle of fuel production is presented in Figure 21.

Table 4. Environmental impact (LCA) of 1 L diesel burned in a car (e.g., small truck)

Amount	CF (kg CO ₂ -eq)	WF (m ³)	N (mol)
1 L diesel	3.23	0.21	0.12

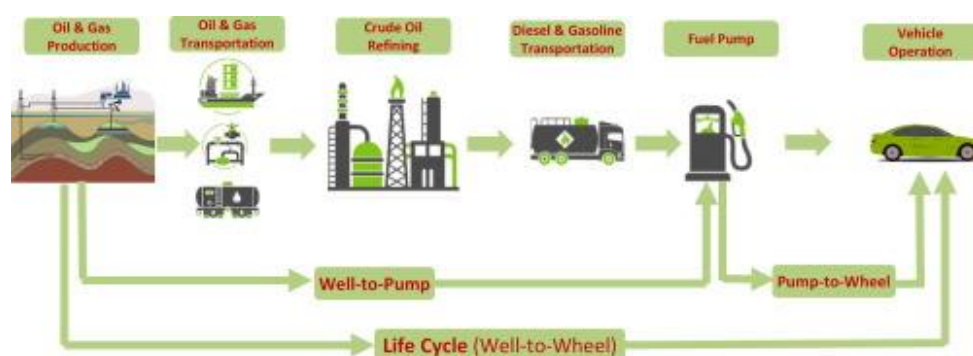


Figure 21. Life Cycle of Fuel production.

Water Footprint (WF): Water Footprint in diesel use is linked to the life cycle of fuel production and distribution. In this case, 0.21 m³ (210 L) of water are consumed for 1 L used in cars. Reducing diesel use also reduces water-related consumption.

Eutrophication (N): Industrial diesel production and transportation overseas leads to the release of 0.12 mols of N per L of diesel, which is considered high. Diesel use has a global impact on terrestrial eutrophication, therefore, its use should be reduced. In the case of SME wineries in Cyprus, options for mitigating diesel fuel use in corporate cars should be explored (e.g., electrical vehicles; hybrid; car-sharing).

5.1.4. Other inputs

In Table 5, the environmental impact is presented from the production of bentonite, yeast, enzymes and sulfur, typical inputs in winemaking. Yeast (Figure 22,23) has the higher CF per kg, followed by enzymes. Bentonite (Figure 24) has the higher WF, followed by yeast which also has the higher eutrophication potential (0.037). Overall, the mitigation of bentonite and yeast amount is the target for reducing the PEF from wine production.

Table 5. Environmental impact (LCA) of 1 L diesel burned in a car (e.g., small truck)

Amount	CF (kg CO ₂ -eq)	WF (m ³)	N (mol)
1 kg bentonite	0.565	0.542	0.008
1 kg yeast	5.578	0.348	0.037
1 kg enzymes	1.047	0.036	0.005
1 kg sulfur dioxide	0.384	0.101	0.006

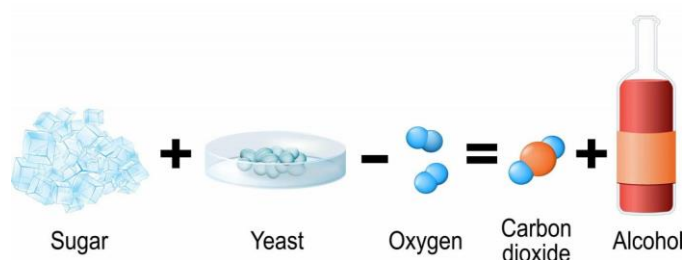


Figure 22. Yeast is a crucial element for wine production. Yeast cells attack the natural sugar molecules in the pressed juice and break them apart to release energy. Some of this energy is given off as heat.

Carbon Footprint (CF): According to the bentonite used in SME wineries, 10 kg per year is considered an optimum amount for reducing GHG emissions in winemaking. The higher its use, the higher the GHG emissions. A range of bentonite use in SME wineries of similar production capacity is 5-130 kg/year. Yeast has a relatively high CF, therefore its use should be minimized, if possible. A typical range of use in SME wineries is 3-40 kg, depending on the production methods. Enzymes' use was

reported to be 0-10 kg per year, using up to 1 kg is preferable for reducing GHG emissions. Sulfur dioxide use is typically 1-20 kg per year and a value close to 10 kg combines the reduction of CF in combination to preserve the quality of the product.

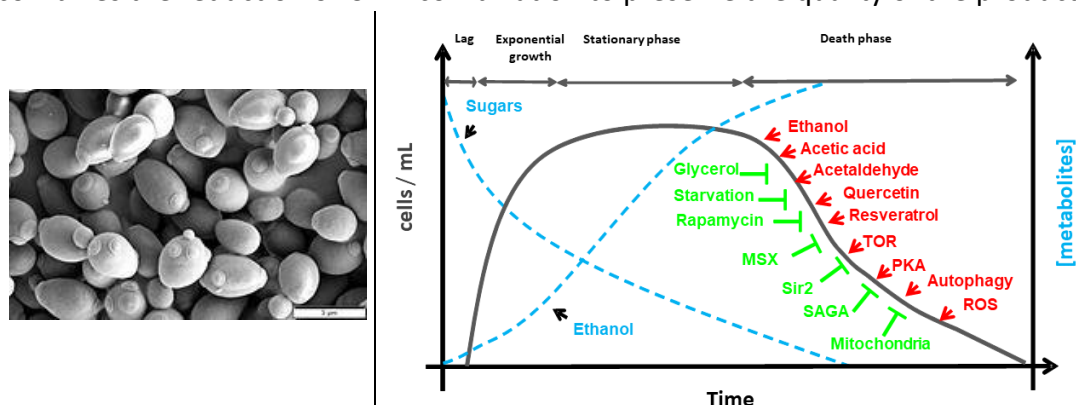


Figure 23. *Saccharomyces cerevisiae* (left) has been instrumental in winemaking, baking, and brewing since ancient times. Right: Growth phases of wine yeast.

Water Footprint (WF) : As for the CF, higher consumption of the inputs presented in Table 2, leads to higher WF. In this case, we are talking about water that is consumed in the industrial processes (e.g., cooling) to produce these inputs. Accordingly, the above paragraph values for the consumption of bentonite, yeast, enzymes, and sulfur dioxide are considered preferable for mitigating the WF.

Eutrophication (N) : Similar to GHG emissions and water use, N is the output of several industrial processes, for the production of the inputs presented in Table 5.



Figure 24. Bentonite is a common addition to winemaking used to clarify wines and is generally used only for white wines. It removes any protein haze and can also be utilized to fine any 'off' aromas.

5.2. Packaging

5.2.1. Glass

Carbon Footprint (CF) : The CF for 1 kg of glass bottle (Figure 25, 26, 27) is 1.01 kg CO₂-eq and a typical 0.75L bottle has 0.55 kg weight. Most of the SMEs in Cyprus have an annual production of 25000-40000 bottles. Larger wineries are producing >100000 bottles per year. In these wineries, reducing the weight of glass and increasing the recycling of glass is essential for CF mitigation.

Water Footprint (WF): Glass industrial production is also water demanding, as for each kg of glass 2.02 m³ of water are required (LCA approach). Reducing the weight of glass bottles or searching for alternatives (e.g., wine in a box) supports WF mitigation.

Eutrophication (N): For each kg of a glass bottle, 0.006 moles of N are released in the environment. As with CF and WF, reducing the weight of glass or the amount of glass bottles results in eutrophication mitigation.

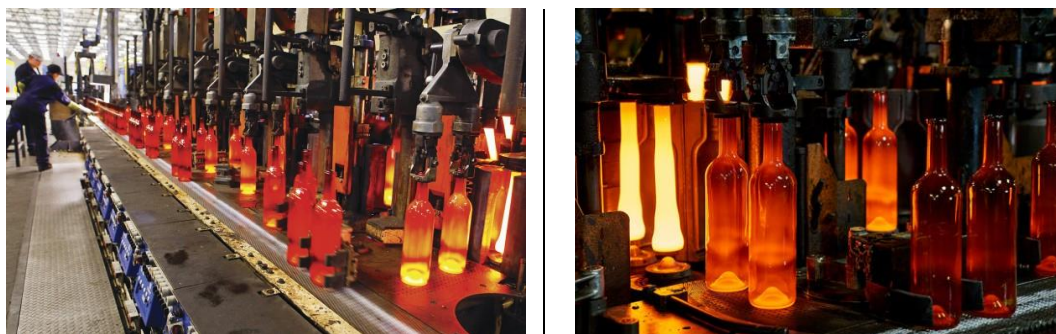


Figure 25. Glass production

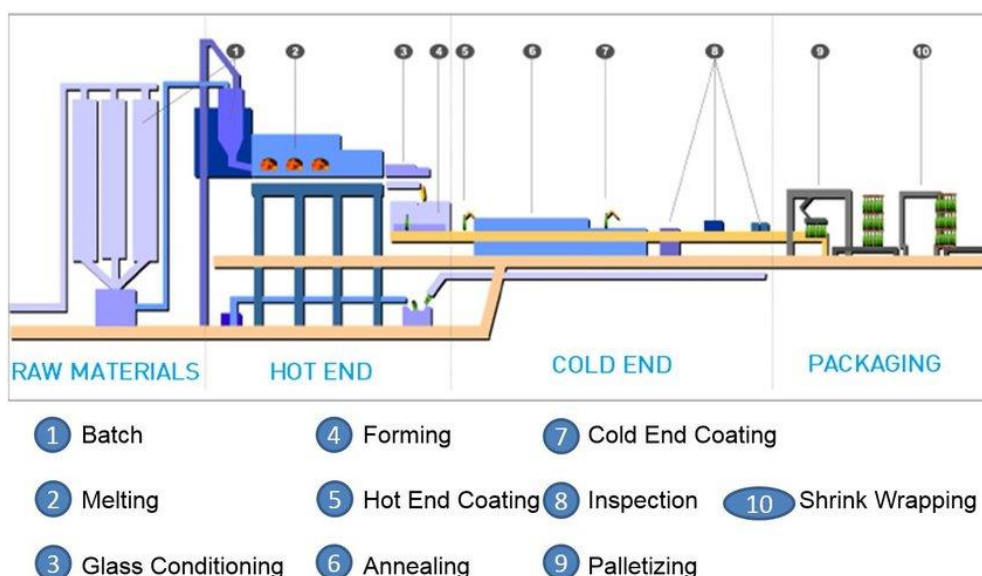


Figure 26. Production of glass containers.



Figure 27. Different options for wine bottles.

5.2.2. Carton

Carbon Footprint (CF): Carton boxes (Figure 28) production also contributes to climate change, as 0.949 kg CO₂-eq are emitted per kg of carton box paper manufactured. Therefore, the target for the wineries is to minimize carton box use.

Water Footprint (WF): The production of carton boxes also consumes water. 1.91 m³ of water are required during industrial processes per 1 kg of carton box.

Eutrophication (N): Carton box production leads to emissions of 0.011 mols of N per kg of carton box. This value is considered high, in comparison to the other inputs studied. Therefore, for the mitigation of PEF of wine, carton use should be minimized.



Figure 28. Various types of carton boxes.

5.3. Retail

Total distance to the market (annual km for wine distribution) is used for the determination of the environmental impacts related to retail. There are two possibilities for the Cypriot SME wineries. They usually distribute their wine to the

market using a van (and making numerous trips to various locations) or a heavy truck (Figure 29). The second option is to hire a company that handle the logistics for transporting the wine to the market. Small (e.g., <30000 bottles/year) wineries commonly follow the first option. In any case, increasing the km the environmental impact is increased. Below, a comparison between the two transportation options is provided. Choosing lorry transport reduced the total km to the market and CF, WF and N is lower per t*km.



Figure 29. Transportation to the market; truck (left) and van (right).

Carbon Footprint (CF): The CF for the option of using a van or light freight commercial vehicle is 1.468 kg CO₂-eq for transporting 1 ton of product for 1 km (t*km). Therefore, for the emissions calculation, the load and the distance is taken into account. When using a van, more trips are required to deliver the produce (e.g., 30000 wine bottles). Therefore, >5000 km per year in the case of Cyprus might be needed. In the case of using a truck (lorry 16 tons freight), the CF is lower; 0.166 kg CO₂-eq/(t*km). It is preferable to transfer the product by lorry to the supermarket or a logistics centre for local distribution. Overseas transport (e.g., imported wine; Figure 30 has higher CF due to increased distance to reach the market).

Water Footprint (WF) : From the LCA approach, the production and use of the vehicles used for wine transport to the market, results in water use. This water is linked to industrial processes and fuel production. In the case of using a van, the WF is equal to 0.14 m³/(t*km). This value is equal to 0.017 m³/(t*km).

Eutrophication (N): N release to the environment also occurs due to the production and use of vehicles. This amount equals to 0.026 mol N/(t*km) in the case of light freight commercial vehicles (e.g., vans) and 0.002 in the case of lorries.



Figure 30. Bulk wine shipping (<https://ibwsshow.com/en/blog/insights-64/bulk-wine-shipping-companies-84.htm>)

5.4. End of life

A percentage of the glass after wine is consumed ends in the landfill (Figure 31). This percentage, according to data collected from the wineries, ranges from 30-75%. Exact numbers are not available. Nevertheless, the target should be zero glass ending in the landfill. However, glass recycling (Figure 32) is also an energy-demanding process, but it cannot be compared to glass production. An option to mitigate the impact of glass production is its reuse, as it minimizes the CF and the other impact indicators.

Carbon Footprint (CF): For each kg of glass ending in the landfill, 0.027 kg CO₂-eq are released, due to processes related to landfill operation (e.g., machinery to handle the waste).

Water Footprint (WF): Additionally, per kg of glass buried in a landfill and according to LCA data, 0.002 m³ of water are consumed in various stages of the life cycle.

Eutrophication (N): Eutrophication is minor, in comparison to other inputs and processes presented in this manual (0.0005 mol N/kg glass).



Figure 31. Landfill.

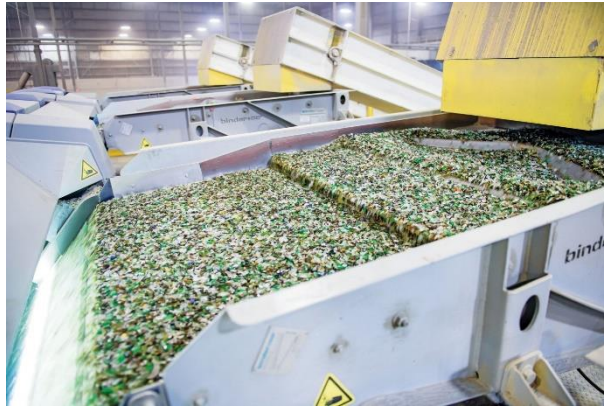


Figure 32. Glass recycling facility.

Based on the analysis of the PEF indicators that was provided, Table 6 presents the evaluation of management practices/inputs impacts on the PEF for wine production. The preferable option for each of the practices/inputs is also provided.

Table 6. Management practices and inputs for winemaking and their effect on PEF and wine production.

Management	Practice	CF	WF	Nitrogen	Wine production	Preferable
Winemaking						
Electricity (kWh)	1-10000					
	10000-20000					
	20000-40000					
	40000-60000					
	> 60000					
Water (m ³) – direct in the winery cleaning purposes.	1-10					
	10-50					
	50-100					
	100-200					
	>200					
L of diesel for transportation (corporate vehicles)	0-400					
	400-800					
	800 - 1200					

	1200-1600					
	1600-2000					
Bentonite (kg per year)	0-10					
	10-50					
	50-100					
	100-150					
	> 150					
Yeast (kg per year)	0-5					
	5-10					
	10-20					
	20-40					
	>40					
Enzymes	0-1					
	1-5					
	5-10					
	10-15					

	>15					
Sulfur dioxide (kg per year)	0-5					
	5-10					
	10-15					
	15-20					
	>20					
Packaging						
Number of glass bottles	0-25000					
	25000-50000					
	50000-75000					
	75000-100000					
	> 100000					
Carton box (number of items)	0-6000					
	6000-12000					
	12000-18000					
	18000-24000					

	24000-30000					
Retail						
Total distance to the market (km per year)	0-6000					
	6000-12000					
	12000-18000					
	18000-24000					
	24000-30000					
End of Life						
% of the glass ending to the landfill	0					
	1-20					
	20-40					
	40-60					
	> 60					

Legend

Very good	Good	Neutral	Bad	Very bad

6. PEF, EU POLICIES AND MARKETING

The European Commission proposed the Product Environmental Footprint (PEF) and Organization Environmental Footprint (OEF) methods as a common way of measuring environmental performance. The 2020 Circular Economy Action Plan foresees that PEF and OEF should be used for the indicators' determination (e.g., Carbon Footprint) for the environmental claims.

This is part of a strategy to establish a common framework for sustainable production. Claims on the environmental performance of companies and products must be reliable, comparable, and verifiable across the EU. Reliable environmental information would allow market actors – consumers, companies, investors – to make greener decisions.

This initiative has close links to other policies announced in the Circular Economy action plan: 1) the revision of EU consumer law (active participation in the green transition), 2) a sustainable product policy initiative, 3) the Farm to Fork Strategy. All these initiatives aim to significantly reduce the environmental footprint of products consumed in the Union and contribute to the overall policy objective of EU climate neutrality by 2050.

To test this framework, the EU during the period 2013-2016 launched the PEF pilots for several products. Among those, the agriculture-related products were: 1) beer, 2) coffee, 3) animal feed, 4) olive oil, 5) pasta, 6) Wine.

The Product Environmental Footprint Category Rules (PEFCR) for wine provides technical guidance on how to conduct a PEF study (https://ec.europa.eu/environment/eussd/smgp/documents/PEFCR%20_wine.pdf).

The winemakers must understand this approach and philosophy and have simple tools to implement it, like those produced by EcoWinery project in the case of Cypriot viticulture and winemaking. There was the first assessment for the way to communicate the PEF (an example is provided in Figure 33).

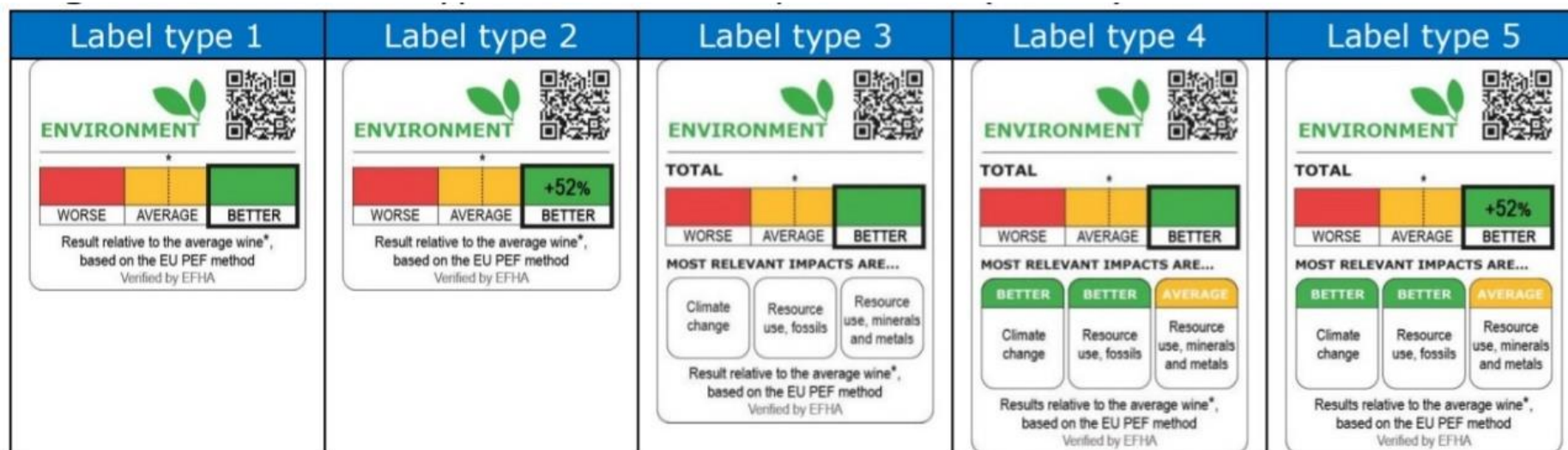


Figure 33. Example of a PEF relevant label (pilot level)

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