Co-funded by the Eco-innovation Initiative of the European Union

Deliverable 2.4: LCA-LCC self-assessment tool on the project website (demo and full version)

WP2. Tuning up a self-assessment tool for wine (LCA-LCC based)

Period reported from: 03/09/2012 to 02/08/2013

ECO-PROWINE - Life Cycle perspective for Low Impact Winemaking and Application in EU of Eco-innovative Technologies

Grant agreement: ECO/11/304386

From 03/09/2012 to 03/09/2015

Prepared by: CIRCE

Date: 03/07/2013

1 Deliverable 2.4: LCA-LCC self-assessment tool on the project website (demo and full version)

The web LCA-LCC self-assessment tool on the project website (demo and full version) in English with the corresponding translations to all project languages can be seen by clicking in the following link:

tool.ecoprowine.eu

D.2.4 “LCA-LCC self-assessment tool on the project website (demo and full version)” is connected to D3.1 “Handbook guide” where the tool is further described. Actually, D3.1 are the specifications of the tool, transformed into a handbook guide. Additionally, the improvement practice sheets developed for the self-assessment tool are presented in Deliverable D 2.5

Finally, a document with the methodology of the LCA/LCC approach and the statistical analysis used inside the tool has been elaborated by CIRCE with supports of all partners (Annex).
Final version of the tool is available nowadays after receive all the information from 84 questionnaires and the results from the statistical analysis made according the methodology described in the Annex.
For both D2.3 and D2.4, a desktop application of the tool is attached to this document and also to the Deliverable of Demo Box. In order to use the desktop application of the tool please unzip the file and go to ECO-PROWINE application.

Co-funded by the Eco-innovation Initiative of the European Union

Annex: Methodology of the LCA/LCC approach and the statistical analysis used inside the ECO-PROWINE tool

ECO-PROWINE - Life Cycle perspective for Low Impact Winemaking and Application in EU of Eco-innovative Technologies

Grant agreement: ECO/11/304386

From 03/09/2012 to 03/09/2015

Prepared by: CIRCE

Date: 31/03/2014

1 Summary

To achieve the minimization of the environmental impacts, the companies' management have to consider a global vision of the whole process, "from the cradle to the grave", so that the resources consumed and the wastes per unit of product were known. This approach involves the use of the Life Cycle and Cost Assessment (LCA-LCC) as a new tool for the environmental management in order to achieve a higher degree of ecoefficiency. The proposed solution (ECO-PROWINE tool) lies on getting user friendly LCA-LCC methodology specialized for the wine chain production. Thereby it is to make available a simplified LCA-LCC on-line available tool that enables wine makers (not expert in LCA methodology) to perform a self-assessment of its wine making process, in order to detect environmental charges, impacts and costs, for each process stage.

The objective of this document is to describe the LCA/LCC methodology and the statistical analysis methodology applied in ECO-PROWINE self-assessment tool. Once this methodology is defined, data gathered from pilot wineries is used for their environmental assessment following the 'ISO 14040:2006 Environmental management -Life cycle assessment - Principles and framework', and the Product Category Rules (PCR) for wine developed by the Life HAproWINE project. LCA approach considers the impact assessment of the Life Cycle Inventory (LCI) from cradle to grave (from the production of bottled wine to end-of-life and waste management of the waste generated in the system). Regarding the LCC assessment, in this approach the cost assessment is related to the direct cost of inputs (from the winery point of view) related to the LCI of the winery including only the production phase for a bottle of wine from vineyard management to the gate of the winery (operating cost). This last approach allows having the proper information for the economical evaluations of the best practices proposed through the ECO-PROWINE tool, based on the cost related to the LCI (general inputs, vineyard management, winemaking and packaging). Evaluation of the cost effectiveness such as the benefit/cost ratio, the internal rate of return, the total life-cycle cost, the annual worth, and the discounted payback period will be done in order to evaluate the cost effectiviness of different alternatives proposed for optimizing the environmental performance of wine-making process. Finally, a decision model based on a statistical analysis of the resources consumption (inputs) e.g water, raw materials, energy consumption, and the environmental impact of wine production using the LCA methodology, is presented. The aim is to facilitate the implementation of actions by wineries indicating environmental and economic benefits. A statistical analysis, as a complementary tool, is used to obtain the specific influencing factors from the winemaking process over the impact indicators related to the environmental impacts from the LCA.

The strategic idea is to foster this methodology among wine producers (105 pilot wineries during the project) and, by this way, achieve a wide market uptake. At the same time, it has to be assured the results scientific, letting us to evaluate the environmental performance of a product over its life cycle that allows evaluating the environmental burdens of the product, process and own activities of the wine production, by identifying energy and materials used and wastes released to the environment.

2 Introduction

According to the Annex I of the Grant Agreement ECO/11/304386, a specific objective of the project is “uptake and wide application Life Cycle and Cost Assessment (hereinafter LCA-LCC) methodology, which need incentives to penetrate significantly the market, in the wine making process”. The proposed solution (ECO-PORWINE tool) lies on getting user friendly LCA-LCC methodology specialized for the wine chain production. Thereby it is to make available a **simplified** LCA-LCC on-line available tool that enables wine makers (not expert in LCA methodology) to perform a self-assessment of its wine making process. After obtaining the results of the assessment, partners of the project will support to wineries (coaching service) to implement the best practices proposed

The European wine sector constitutes a very diversified and dynamic sector in continuous evolution where it is needed to analyse the environmental impact caused by the production process. In spite of the fact that the principles of viticulture and wine production are the same throughout the world; natural, economic, social and technological conditions of individual producers can be very different.

The simplified methodology aim to provide a simplified method for wine makers which achieve to bridge barriers to LCA use by providing a basic lesson in what LCA is, what it can be used for and how it can be performed, all adapted to the winemaking process.

3 Life Cycle Assessment approach

LCA methodology has been used to evaluate the environmental impacts of each of the stages under consideration. This provides a structured analysis of inputs and outputs at each stage of the life cycle of products and services [1]. The Society of Environmental Toxicology and Chemistry (SETAC)[1] defines LCA as an objective process for evaluating the environmental burden associated with a product, process, or activity. This evaluation is achieved by performing the following steps: (i) identifying the energy, materials, and all types of waste that are released to the environment; (ii) determining the environmental impact of energy consumption and of the materials released to the environment; (iii) evaluating and implementing environmental improvement practises. Assessment is performed on the entire life cycle of the process or activity, including the extraction and processing of raw materials, manufacturing, transportation, distribution, use, recycling, reuse, and final disposal. In other words, LCA

[1]Society of Environmental Toxicology and Chemistry: www.setac.org

studies include the environmental aspects and potential impacts of a product throughout the product's life, i.e., from cradle to grave, from procurement of raw materials to production, use, and disposal [2].

The methodology described above is standardised by the ISO 14040:2006 [3, 4]. The assessment process is divided into four basic steps: (1) defining the goal and scope of the analysis; (2) inventory analysis; (3) impact assessment; and (4) interpretation. Figure 1 and Table 1 shows the main phases of the LCA study and illustrates the dynamic character and the relationship of the four phases.

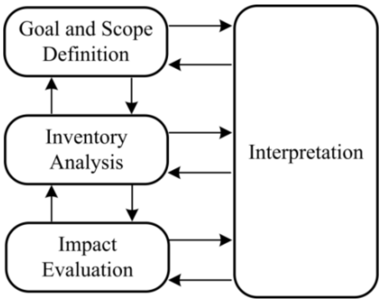

Figure 1 Main phases of an LCA study
Source: [4]

Table 1. LCA stages

Goal and scope definition	Inventory analysis	Impact assessment
	Use of databases/EPD	Use of methods (ReCiPe, Cumulative Energy Demand)
• Purpose of the study • Limits of the system • Necessary data, etc.	Inventory of raw materials, energy and emissions to air, water and soil during the life cycle of the system.	Classification and evaluation of the inventory data in impact categories.
Interpretation		
• Analysis of the results • Conclusions and recommendations		

ISO 14040:2006 prescribes a clear definition of the objective and scope from the beginning of the LCA studies, including system boundaries and functional units. After this stage, inventory analysis is performed by data collection within system boundaries.

As mentioned before, the LCA methodology of the ECO-PROWINE LCA-LCC tool follows the ISO 14025, ISO 14040 and ISO 14044 standards. The terms and definitions from these standards are used in this document. Also, the environmental performance is declared according to the Product Category Rules (PCR) for wine from the LIFE HaproWINE project[2].

[2] Life HAproWINE: Integrated waste management and life cycle assessment in the wine industry. From waste to high-value products. LIFE08 ENV/E/000143. http://www.haprowine.eu/

3.1 Product category

Following the aforementioned product category rules, the approach of the tool apply to wine from fresh grapes (Corresponding to Heading 2204 of the Combined Nomenclature 2013 of the European Commission), regardless of variety in colour, sugar content or age. In this sense, sparkling wine is not included. Within the scope of the tool, includes wine produced in different European geographical areas (not only the countries included in the project), under protected appellation of origin or not, using agricultural practices and/or different production processes and presented with different packaging formats. Also, the wide scope of the project allows evaluating the traditional and ecological farming.

3.1.1 Life cycle phases, corresponding information and module inclusion

Figure 2 shows the generic system description of the process studied.

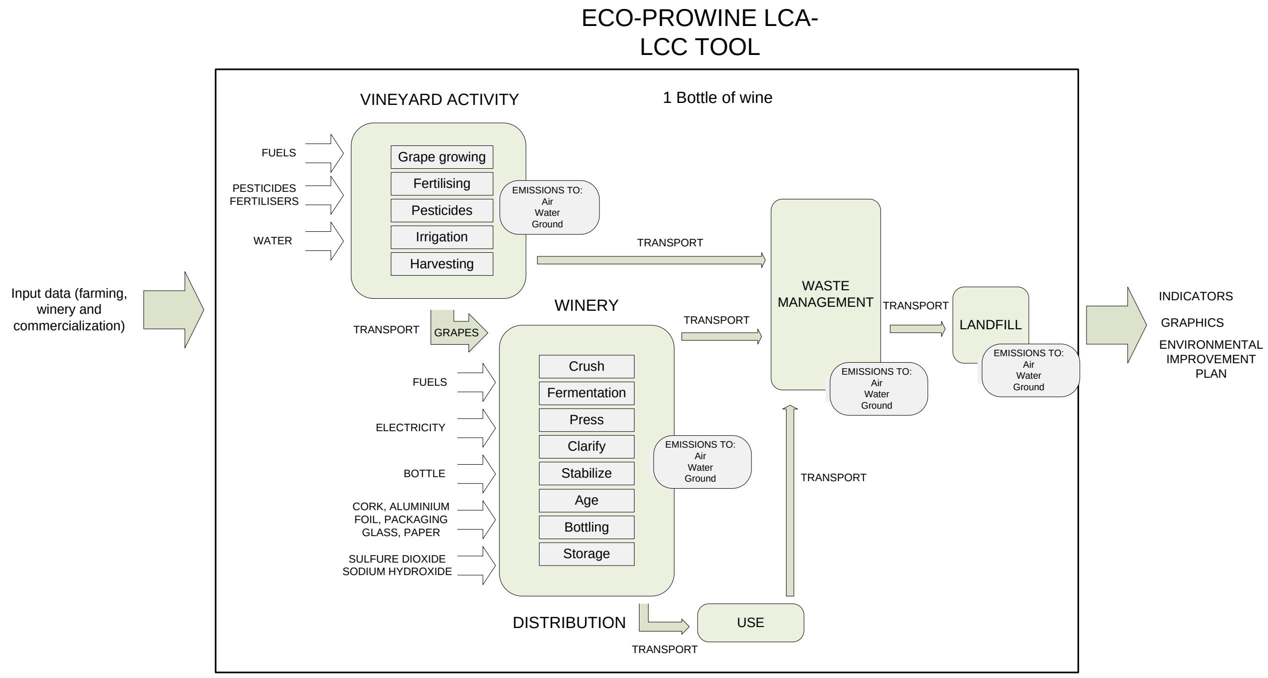

Figure 2 Generic system description of the process studied.

Following the structure proposed by PCR for wine, Life cycle phases are structured in 3 main phases: production of a bottle of wine, distribution and consumption, and end-of-life. Each of these phases is arranged into different information modules, as seen in Figure 3. In terms of scope, the ECO-PROWINE approach follows cradle to grave (including all phases).

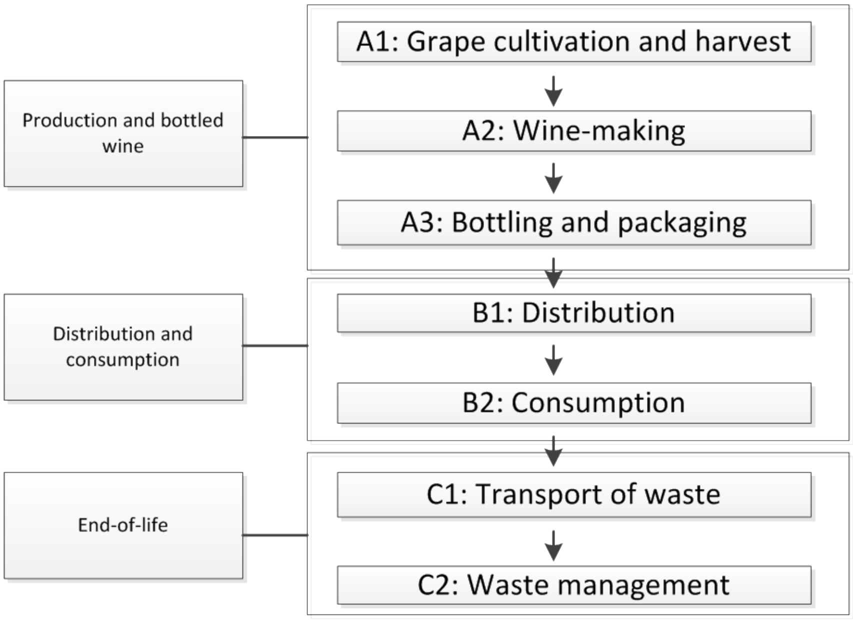

Figure 3 Phases and information modules for the assessment of wine

3.2 Calculation rules for LCA

3.2.1 Functional unit

The functional unit is the unit of reference for all the inputs and outputs of the system to be obtained from Inventory Analysis [5]. In this case, the functional unit is 1 litre of wine produced during the season considered. It includes the primary packaging (bottle and capsule) and secondary packaging (e.g. distribution box). Based on this functional unit and the Life Cycle Inventory, some comparative results can be analysed also in terms of 1 kg of grape or per 1 bottle of wine (750ml).

3.2.2 Reference useful life of reference product

Since wine is sold within days of few months, from a temporal point of view, following the PCR for wine, it may be considered a product with a high market turnover. Therefore, the effect that wine storage may have related to other stages is negligible. Therefore, this effect is excluded from the LCA approach of the tool.

Also, as mentioned in the PCR for wine: "*CO_2 fixation in the vine will also be excluded from the LCA study due to uncertainty concerning its calculation; a sufficient consensus in the scientific community does not yet exist. In future revisions of these PCR, the possibility of including this* *effect based on the methodological advances should be further addressed*". In this sense CO_2 fixation is also excluded from the LCA approach of the tool.

3.2.3 System boundaries

System boundary selection lies with the availability of data needed for the Assessment. Since holdings growing grapes for wine are in general small, a detailed data on the distribution of the general inputs e.g. electricity or water consumption, among the internal processes of the vineyard activity and winery can represent a high economical and human resources and might be unaffordable for most wineries of minor dimension, as are the large majority of EU wine producers. Since the main objective of the project is to make available a simplified LCA-LCC on-line tool, within the boundaries of the MSW management system under study, attention was paid to:

- Winery level study instead of a specific type of wine.
- SMEs wineries (boundary of the study)

According the PCR for wine, general system boundaries of the LCA approach of the tool are defined according to the following principles:

- Modularity principle: the processes (including their environmental impacts) are allocated to the module during which they are produced.
- "Polluter pays principle": waste treatment processes are allocated to the product system that generates the waste, until the final waste condition is reached (waste end-state).
- The recycling waste processes are allocated to the system that will use the derived raw materials.
- Waste from the studied system that will be recycled will forms part of a different product system, without the allocation of environmental credits to the evaluated product system. In this sense, the environmental impacts related to waste generation considers only the treatment methods and not the avoided environmental impacts to produce possible recycled materials.

3.2.4 Criteria for the exclusion of inputs and outputs

To evaluate the environmental implications of each of the considered stages, the following system boundaries were selected:

- Energy and material flows representing more than 1% of the total energy or mass, respectively that enter or leave each of the modules are considered.

- Components representing less than 1% of the total economic value of the product are not considered.
- No stages that contribute less than 1% of the inventory analysis or less than 1% of the total environmental impact are considered.
- The sum of the excluded flows may not exceed 5% of the energy and the total materials used in the entire life cycle of the product
- Inputs or outputs flows that are dangerous to human health or ecosystems according to legislations, regulations, scientific evidence and relevant environmental impacts are included.
- Second-order boundaries are defined considering the phases of production and the production of energy and raw materials for each component.
- Internal transportation is excluded, with exception of that related to fuel consumption to cultivation and tillage operations.
- Transport of the raw materials to the winery, including packaging materials is excluded.
- Transport of waste generated in the winery to the treatment plant is excluded.
- The production of the infrastructure which includes: the construction of the winery, machinery used, plantings and equipment are excluded.
- CO_2 emissions from biological sources are considered neutral[3]. In this case the approach of the tool follows this criteria as is explained in the example presented in the PCR of wine: "the atmospheric C that is fixed during the growth of the grape (through photosynthesis) or the CO_2 emissions from fermentation or biological decomposition of organic waste, are not included in the inventory". Thereby, CO_2 emissions from fossil fuels are included in the inventory.

3.2.5 Data selection

The data selection for the ECO-PROWINE tool was made taking into account specific data from the studied system, especially in the production phase. Also considering literature research, own experiences and previous projects that the partners have implemented. A full list of Inputs was created following the criteria defined in the *Criteria for the exclusion of inputs and outputs* and considering the life cycle phases. A matrix has been developed, including the main inputs of vineyard management and winemaking. The inputs considered are presented in the Annex I: Inputs and measurements methods of the Handbook guide (Deliverable 3.1 of the ECO-PROWINE project).

[3] Following the recommendations of the Intergovernmental Panel on Climate Change (IPCC).

The same matrix has been used from one side to implement the on-line tool (quick assessment and detailed assessment), on the other side to structure a questionnaire to be proposed to wine producers, with the goal of obtaining a first database set.

A complete description of the questionnaires development and its dissemination have presented in D2.1 Result on-line questionnaire for LCA-LCC wine database. Two versions of questionnaires were created in order to collect data from wineries (questions were selected through a preventive selection of the data which are likely to have most influence on the sustainability level of a winery):

- Short version: 24 questions proposed through a web based tool and allowing the identification of the interested persons and later direct contacts (Annex 1, D2.1 Result on-line questionnaire for LCA-LCC wine database)
- Full questionnaire: 112 questions ordered in a Word document to be filled within a given set of time and sent back to project representative. These set of questions corresponds to the first assessment of pilot wineries from period May 1st 2011 – April 30th 2012 (Annex 2, D2.1 Result on-line questionnaire for LCA-LCC wine database).

In this sense, specific data from the studied system will be used in the ECO-PROWINE tool.

On the other hand, generic data from the Software SimaPro v. 7.3 and the commercial and free databases e.g. EcoInvent and ELCD databases has been used. These databases include a detailed Life Cycle Inventory of each input used in the winery process. For example, when we refers to electricity consumption of 1kWh, the electricity mix according the country is used in terms of the environmental impacts al characterization level (18 midpoint indicators).

3.2.6 LCA Databases

All software applications that perform LCA studies include various databases that are used within the stage of LCI (Life Cycle Inventory). It should be noted that calculations have been done using data from a single database or by combining information from different databases, depending on the quality of data that have been identified for the study. In addition most software allows the user to edit the databases included and create new ones.

Some examples of databases for studies of LCA are:

- EU's ELCD core database (http://lca.jrc.ec.europa.eu/lcainfohub/index.vm): it comprises LCI data from front-running EU-level business associations and other sources for key materials, energy carriers, transport, and waste management. Focus on data quality, consistency and applicability.

- Ecoinvent v2.0 (http://www.ecoinvent.ch/): the Ecoinvent data v2.0 contains international industrial life cycle inventory data on energy supply, resource extraction, material supply, chemicals, metals, building materials, waste management services, and transport services. The version 3.0 with new datasets and system models was released in May 2013.
- Also it is possible to obtain inventory data from EPDs (Environmental Product Declarations), which are Type III declarations (third party control, ISO 14025). Information about EPDs can be found in the International EPD® system web site (http://www.environdec.com) and the GEDnet web site (http://www.gednet.org).

3.2.7 Impact Assessment

The impact categories to analyse in this project were selected considering the current energy and environmental problem in the European area, and the need to reach the 20-20-20 targets. Therefore the impact categories considered in this project are:

- Primary energy demand (MJ-Eq) according to the Cumulative Energy Demand-CED method,
- Climate change (kg CO_2 eq), Ozone depletion (kg CFC-11 eq), Human toxicity (kg 1,4-DB eq), Photochemical oxidant formation (kg NMVOC), Particulate matter formation (kg PM10 eq), Ionising radiation (kg U235 eq), Terrestrial acidification (kg SO_2 eq), Freshwater eutrophication (kg P eq), Marine eutrophication (kg N eq), Terrestrial ecotoxicity (kg 1,4-DB eq), Freshwater ecotoxicity (kg 1,4-DB eq), Marine ecotoxicity (kg 1,4-DB eq), Agricultural land occupation (m^2a), Urban land occupation (m^2a), Natural land transformation (m^2), Water depletion (m^3), Metal depletion (kg Fe eq), Fossil depletion (kg oil eq) according to the ReCiPe midpoint method, hierarchist version with European normalisation,
- Water demand (in m^3)

Cumulative energy demand

The CED method has been used since the seventies as an indicator for energy systems. It states the entire demand is assessed as the primary energy which arises in connection with the production, use and disposal of an economic good (product or service) or which may be respectively attributed to it through cause. The CED distinguishes between non-renewable (fossil and nuclear) and renewable primary energy use (hydraulic, biomass, wind, solar and geothermal).

Impact assessment Methodology (ReCiPe)

In the ECO-PROWINE tool, environmental impacts were determined from a *midpoint*-level approach. A *midpoint* impact category indicator is considered to be a point resulting from the cause-effect (environmental mechanism) relationship of a particular impact category with respect to the causative factor (a set of conditions that can lead to an impact) and an *endpoint*-level impact category indicator [1]. In other words, *midpoint* methodologies define environmental effects (e.g., acidification, global warming) without identifying the damage caused to human health and to ecosystem quality, as do *endpoint* methodologies.

Taking into account the phases of impact assessment (classification, characterisation, normalisation, and weighting) at the *midpoint* level, the characterisation factors applied to each impact category correspond to those proposed by the ReCiPe method [6, 7]. ReCiPe is one of the most recent and harmonised indicator approaches. This method calculate eighteen midpoint indicators (Table 2). These indicator scores express the relative severity on an environmental impact category. A description of these indicators can be found in [6].

Table 2. ReCiPe midpoint indicators

Name	Unit
Climate change	kg CO_2 eq
Ozone depletion	kg CFC-11 eq
Human toxicity	kg 1,4-DB eq
Photochemical oxidant formation	kg NMVOC
Particulate matter formation	kg PM10 eq
Ionising Radiation	kg U235 eq
Terrestrial acidification	kg SO_2 eq
Freshwater eutrophication	kg P eq
Marine eutrophication	Kg N eq
Terrestrial ecotoxicity	kg 1,4-DB eq
Freshwater ecotoxicity	kg 1,4-DB eq
Marine ecotoxicity	kg 1,4-DB eq
Agricultural land occupation	m^2a
Urban land occupation	m^2a
Natural land transformation	m^2
Water depletion	m^3
Metal depletion	kg Fe eq
Fossil depletion	kg oil eq

Water demand (in m^3)

No method has been yet developed for incorporating desiccation into the LCA as desiccation potential. The indicator selected for this study aggregates all freshwater extractions (from rivers, lakes, soil and wells) including water used for cooling processes but excluding water used in turbines in hydraulic power production.

LCA Software (impact Assessment)

One kg of material is mainly the selected functional unit for all inputs. The European averages of the Ecoinvent v2.0 database (2007) inventories were selected to develope this generic database. As we are dealing with average data, its applicability to each European country depends on the level to which its specific characteristics (energy mix, manufacture technology, origin of the starting materials, etc.) are adapted to these averages. The software tool used to assess the life cycle impacts is SimaPro v7.3.2.

3.2.8 Evaluation

The evaluation is achieved by performing the following steps (for more information please see the Handbook guide (Deliverable 3.1 of the ECO-PROWINE project):

- Identifying the energy, materials, and all types of waste that are released to the environment;
- Determining the environmental impact of energy consumption and of the materials released to the environment;
- Evaluating and implementing environmental improvement practices

4 Life Cycle Cost Assessment Approach

Life cycle and cost assessment measure environmental performance and cost of activity of every winery. The LCA and LCC methods are together life cycle technique tools. Furthermore, the time horizons of their research goals are the same. It means: from cradle to grave. The differences between LCA and LCC are unfortunately more obvious i.e.: data on the complete set of upstream processes are necessary for the calculation of the total environmental impact in LCA (based on commercial and free databases e.g. EcoInvent and ELCD), while in LCC we speak about cost. It provides that the price can be sum up but the impact cannot. It means the total cost is sum up by cost of each step during the life cycle.

On the other hand, both of these tools need to make calculations through getting data from the database. The LCA focus on the environmental impact in the future and LCC concerns on long term benefits. Since there is no database of costs related to each inputs in wineries, the cost assessment is related to the direct cost of inputs (from the winery point of view) related to the Life Cycle Inventory of the winery including only the production phase for a bottle of wine from vineyard management to the gate of the winery (operating cost). This last approach allows having the proper information for the economical evaluations of the best practices proposed through the ECO-PROWINE tool, based on the cost related to the LCI (general inputs, vineyard management, winemaking and packaging). In this sense, cost calculated, for the moment, are based on the real costs the winery will declare.

5 Statistical analysis

In this study several regression models are going to be selected to find a compromise between the simplicity of the evaluation method and the accuracy in the result without requiring a considerable amount of input data and simulation energy (the data collected of energy is the global consumption) from the wineries under analysis. Multiple regressions is used frequently in research; the present work aims to identify explicative variables to develop a model in which the chosen variables influence the response and the variables that do not contribute relevant information are rejected.

The objectives of this study are to develop a regression model that determines how sustainable a winery is in terms of environmental, economic and social impacts, depending on its vineyard, winery and social management by predicting which are the factors that influence more in the impacts the wineries cause from their activity. The mathematical model permits researchers to predict the variables influencing the impacts without widespread analysis and to propose impact improvement measures that could reduce their resources, wastes or social impacts. The results provide relevant information on the sustainable performance of the European winery sector and contributes with new data.

An inference analysis is developed to obtain different multiple regression models for the prediction. The aim was to first obtain a model that will serve as a pre-diagnostic tool for sustainable performance in the wineries analysed, and the models are based on easy-to-obtain variables from the questionnaires sent to the wineries, precluding the necessity of a walkthrough audit.

Relevant independent variables that define the sustainable performance were selected, and included in a questionnaire sent to the European wineries with more than 100 questions, to develop models that were obtained by means of regression models. Regression coefficients are estimated using the least squares method. This method estimates the regression coefficients by minimising the sum of the squares of the deviations to the proposed regression model [8]. A regression equation is as shown:

$$\hat{Y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p \quad (1)$$

where $\hat{Y}$ is the fitted value and β_0, β_1, …, and β_p are the estimations of the regression parameters.

The real value for Y is:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \varepsilon \quad (2)$$

where ε is the random error [9].

β_0, β_1, …, β_p describe the expected change in the predicted variable Y in response to a unitary change in x_i when the rest of predictors remain constant [10].

It is not recommended to predict the response variable for a set of values for predictors that are out of the range of data used for the regression equation obtained, which would lead to an extrapolation error [11]. The graphical and regression analysis are performed using Minitab and SPSS.

Questionnaires of the project, which consist of a set of 112 questions about vineyard and winery production and management as well as packaging, will be the instrument for the 105 wineries sample data collection, afterwards, the statistical model will be obtained including the influencing variables from the winemaking process. The statistical analysis developed in this work can support, on the one hand, the selection of 'best practices' addressing, in an efficient and effective way, and, on the other hand, the specific weak points of the winemaking process, which should be improved to reduce the energy and resources consumption of wine production sector. In addition, it helps to make that SMEs wineries do not incur in unnecessary investments which could have less impact in terms of environmental performance.

REFERENCES

1. Tukker, A., *Life cycle assessment as a tool in environmental impact assessment.* Environmental Impact Assessment Review, 2000. 20(4): p. 435-456.
2. Aranda Usón, A. and I. Zabalza Bribián, *Ecodiseño y Análisis de Ciclo de Vida*2010: Prensas Universitarias de Zaragoza.
3. Guinee, J., et al., *Life cycle assessment - an operational guide to the ISO standards*, 2001, Centre of Environmental Sciences (CML): Leiden University
4. International Organization for Standardization, *ISO 14040:2006, Environmental Management – Life Cycle Assessment – Principles and Framework*, in *International Organization for Standardization*2006: Geneva, Switzerland
5. Rebitzer, G., et al., *Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications.* Environment International, 2004. 30(5): p. 701-720.
6. Recipe. *Recipe Website.* 2011; Available from: www.lcia-recipe.net.
7. Goedkoop, M.J., et al., *ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I:*

Characterisation, 2009, Ministry of housing, spatial planning and the environment (VROM): The Netherlands.

8. Peña, D., *Regresión y Diseño de Experimentos*2002, Madrid: Alianza Universidad Textos.
9. D. C. Montgomery, G.C.R., *Probabilidad y Estadística Aplicadas a la Ingeniería*. second ed2004, Mexico D.F.: Limusa Wiley.
10. N. R. Draper, H.S., *Applied Regression Analysis*. third ed, ed. Wiley1998, New York: Wiley.
11. J. Neter, M.H.K., C. J. Nachtsheim, W. Wasserman, *Applied Linear Statistical Models*. fourth ed1996, Chicago: WBC/McGraw-Hill.