# Mechanisms to promote Circular Economy in agricultural sector – Life Cycle Assessment of olive oil production in Portugal

***Emilia Weronika Cichoń***

*emilia.cichon@gmail.com*

*Instituto Superior Técnico, Universidade de Lisboa, Portugal*

*November 2018*

## Abstract

Nowadays a crucial goal for the world is to search for a more sustainable future in all sectors of our lives. The solution for reducing environmental impacts is introducing the concept of Circular Economy. The agricultural sector is no exception, and the olive oil industry has a great importance in the European economics. It is crucial to understand and manage the impacts associated with this sector, as well as identify and apply the good practices in order to change the economic model from linear to circular.

This work presents the Life Cycle Assessment of the olive oil production in region Alentejo, Portugal. It compares two different scenarios - conventional production and production with the implementation of good practices identified in the sector. The proposed solution in Good Practices Scenario includes energetic valorisation of olive stones, through direct combustion to produce electricity in the vapour cycle. The results show that the electricity production from olive stones is possible and this solution can be implemented in the olive oil mill. However, overall, the environmental impacts associated with it are slightly higher than in the conventional method. Regarding cost analysis, the proposed solution requires high investment, with a payback period of 7 years and 5 months and a Return On Investment (ROI) of 33.5% at year 10. However, it creates a possibility of generating income and at the same time re-using by-products of olive oil production. Finally, the suggestions and possible further actions were proposed for this case study.

**Keywords**: Olive oil, Life Cycle Assessment, Circular Economy, Agriculture, Biomass, Energy

## 1. Introduction

Nowadays a crucial goal for the whole world is to search for a more sustainable future in all sectors of our lives. The global objectives are to reduce the environmental impact, energy consumption, and costs associated with each sector. The solution for reducing the environmental footprint is introducing the concept of circular economy. This way it would be possible to preserve the resources, which are already in use in the economy while keeping them at their highest economic value for a longer time.

Consequently, the need to extract so many raw materials would not be so high, which would lead to reduced waste production and smaller environmental impact. [1]

All sectors of economy are becoming more and more globalised and industrialised, and food production and consumption is no exception. In all the developed countries, agricultural practices have been intensified in order to increase the effectiveness of production. That is why agri-food is considered one of the sectors with great impact on human capital employment, nutritional security, but also on environmental sustainability because of the big inputs of the resources. [2]

Olive oil, according to the International Olive Oil Council, is a typical Mediterranean product that has great importance in the economics of the European Union, in both production and consumption stages. Moreover, in many countries the olive oil industry causes different environmental impacts in terms of depletion of the resources, land degradation, waste generation and air emissions. These impacts vary from one country to another, depending on the practices and techniques applies in olive trees cultivation and olive oil production. Depending on these different practices and techniques, the production of olive oil is associated with several effects on the environment. It is crucial to understand and manage the environmental impacts related to the production of olive oil, with an in-depth analysis of the good practices and techniques that can be applied in this industrial sector. Consequently, tools such as Life Cycle Assessment are becoming increasingly important for this type of industry. [3]

# 2. Methodology

## 2.1. Case study

The case study was conducted in cooperation with the company Instituto de Soldadura e Qualidade (ISQ), within the project “Alentejo Circular”, that focuses on implementing the concept of circular economy to the agricultural sector in Portugal. Part of the data needed in the case study comes from ISQ’s reports on the project [4] and was obtained from local companies that produce olive oil in Alentejo region. The rest was supplemented with the literature data. The Life Cycle Assessment was performed using the computer software SimaPro.

Due to the constraints experienced in acquiring in due time all the data needed from a real olive oil producer, this work presents a hypothetical company, which characteristics are based on interviews with people working in one of the biggest companies producing olive oil in Portugal and data acquired from the project “Alentejo Circular”. The company has an olive trees plantation, so they use olives of their own production. The product studied in this work is extra virgin olive oil, and after production, the oil is stored in tanks and then sent to the companies that put it into bottles. Therefore the functional unit in this case study is 1 l of olive oil produced. The analysed mill works 24 hours per day, for five months during the year (it is dependent on the olives harvesting time), which gives 3600 hours of the operation.

This case study focuses on the industrial phase of olive oil production, so the impacts associated with olive oil production are considered from the moment of reception of the olives to the mill. Since the purpose of the study is to compare the impacts from in the olive oil manufacturing stage, the analysis does not include the olives cultivation phase, because the impacts associated with this phase are the same in both scenarios and they do not influence the results.

In this work the emphasis is given on improving the present practices of Portuguese companies from the sector of olive oil production. It includes one case with two Life Cycle Assessments, for the current situation of the company (Business As Usual), and the future scenario after implementing the proposed solution (Good Practices Scenario).

### 2.1.1. Business As Usual Scenario

The first scenario – Business As Usual, considers the conventional method of olive oil production. The olive mill uses the continuous centrifugation with the 2-phase system, which means that the main products obtained in the process are olive oil and olive wet pomace. All the crucial stages of the processing of olives to get the ready product are: reception of olives, olives washing, leaves removal, crushing, malaxing and centrifugation (2-phase decanter). Table 1 presents inputs and outputs considered in LCA for this scenario.

*Table 1 Primary data for olive oil processing, per 1 l of olive oil - Scenario 1 (Business As Usual)*

| **Inputs** | | |
|---|---|---|
| **Name** | **Unit/1 l of olive oil** | **Amount** |
| Olives | kg | 6.617 |
| Water | l | 1.263 |
| Electricity | kWh | 0.295 |
| Diesel | kg | 0.0004 |
| **Outputs** | | |
| Olive oil | l | 1 |
| Olive wet pomace | kg | 6.200 |
| Olive stones | kg | 0.541 |
| Leaves | kg | 0.190 |
| $CO_2$ | kg | 3.260 |

### 2.1.2. Good Practices Scenario

Since one of the assumptions of the Circular Economy is “reuse”, the Good Practices Scenario includes a proposed solution for the waste valorisation. Energy recovery from olive oil mills residues is an interesting alternative to the disposal of these wastes. It can also reduce the environmental impacts and at the same time to generate electric energy to satisfy the needs of the mill or for sale. In general, the residual biomass from olive processing that has the potential for energy use can be divided into two groups.

The idea in this work is to use olive stones that are a by-product of olive oil processing (contained in the olive pomace), and they are treated as waste, while they have good potential to be used in energy recovery. The olive stones are obtained by the separation from the pulp (pomace) and dried in the outside space, so they are ready to be used as a fuel. [5]

Figure 1 presents the designed vapour cycle to produce electricity from olive stones. Cycle is powered by the electricity from the grid and the electricity generated from the cycle will be used for the own needs of the mill and the remaining electricity will be sold back to the grid.

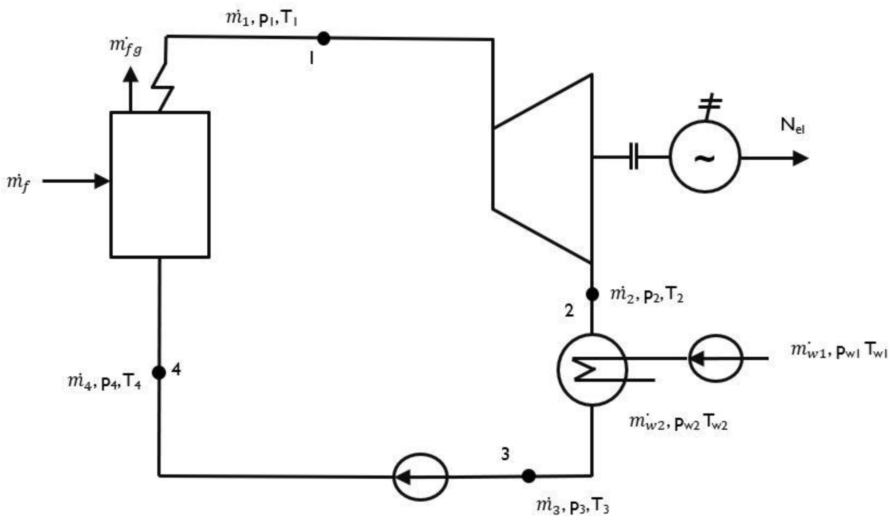


*Figure 1 Vapour cycle for the proposed solution*

Table 2 presents the most relevant parameters used and calculated for the considered cycle.

*Table 2 The most relevant parameters calculated for the cycle*

| Name of the property | Symbol | Unit | Value |
|---|---|---|---|
| Pressure of the steam at the exit of the boiler | $p_1$ | bar | 17 |
| Temperature of the steam at the exit of the boiler | $T_1$ | °C | 300 |
| Enthalpy of the steam at the exit of the boiler | $h_1$ | $\frac{kJ}{kg}$ | 3020 |
| Entropy of the steam at the exit of the boiler | $s_1$ | $\frac{kJ}{kg°C}$ | 6.85 |
| Mass stream of fuel | $\dot{m}_f$ | $\frac{kg}{s}$ | 0.161 |
| Lower Calorific Value of the fuel | LCV | $\frac{MJ}{kg}$ | 18.34 |
| Chemical energy o the fuel | $\dot{E}_{ch,f}$ | $\frac{kJ}{s}$ | 2949.99 |
| Efficiency of the boiler | $\eta_B$ | % | 87.5 |
| Mass flow rate of the steam at the exit of the boiler | $\dot{m}_1$ | $\frac{kg}{s}$ | 2.93 |
| Pressure of the steam at the exit of the turbine | $p_2$ | bar | 0.08 |
| Enthalpy of the steam at the exit of the turbine | $h_2$ | $\frac{kJ}{kg}$ | 2140 |
| Internal power of the turbine | $\dot{W}_t$ | MW | 2.58 |
| Enthalpy of the steam in state 3 | $h_3$ | $\frac{kJ}{kg}$ | 173.88 |
| Thermal efficiency of the cycle | $\eta$ | % | 30.9 |

| | | | |
|---|---|---|---|
| Heat delivered to the boiler | $\dot{Q}_{in}$ | MW | 8.3 |
| Electrical power generated in the cycle | $N_{el}$ | MW | 2.45 |
| Mass flow rate of cooling water | $\dot{m}_{cw}$ | $\frac{kg}{s}$ | 51.09 |

Table 3 presents inputs and outputs used in the LCA for this scenario.

*Table 3 Primary data for olive oil processing, per 1 l of olive oil - Scenario 2 (Good Practices)*

| **Inputs** | | |
|---|---|---|
| **Name** | **Unit/1 l of olive oil** | **Amount** |
| Olives | kg | 6.617 |
| Water | l | 1.263 |
| Electricity | kWh | 0.015 |
| Olive stones | kg | 0.590 |
| **Outputs** | | |
| Olive oil | l | 1 |
| Olive wet pomace | kg | 6.200 |
| Olive stones | kg | 0.541 |
| Leaves | kg | 0.190 |
| Electricity | MWh | 0.0023 |

## 3. Results and discussion

Figure 2 presents the comparison of characterisation between the two analysed scenarios. Almost in all impact categories, Scenario 1 performed better than Scenario 2. Only in two categories: Climate change Human Health and Climate change Ecosystems, Scenario with Good Practices obtained better results, and the difference is huge.

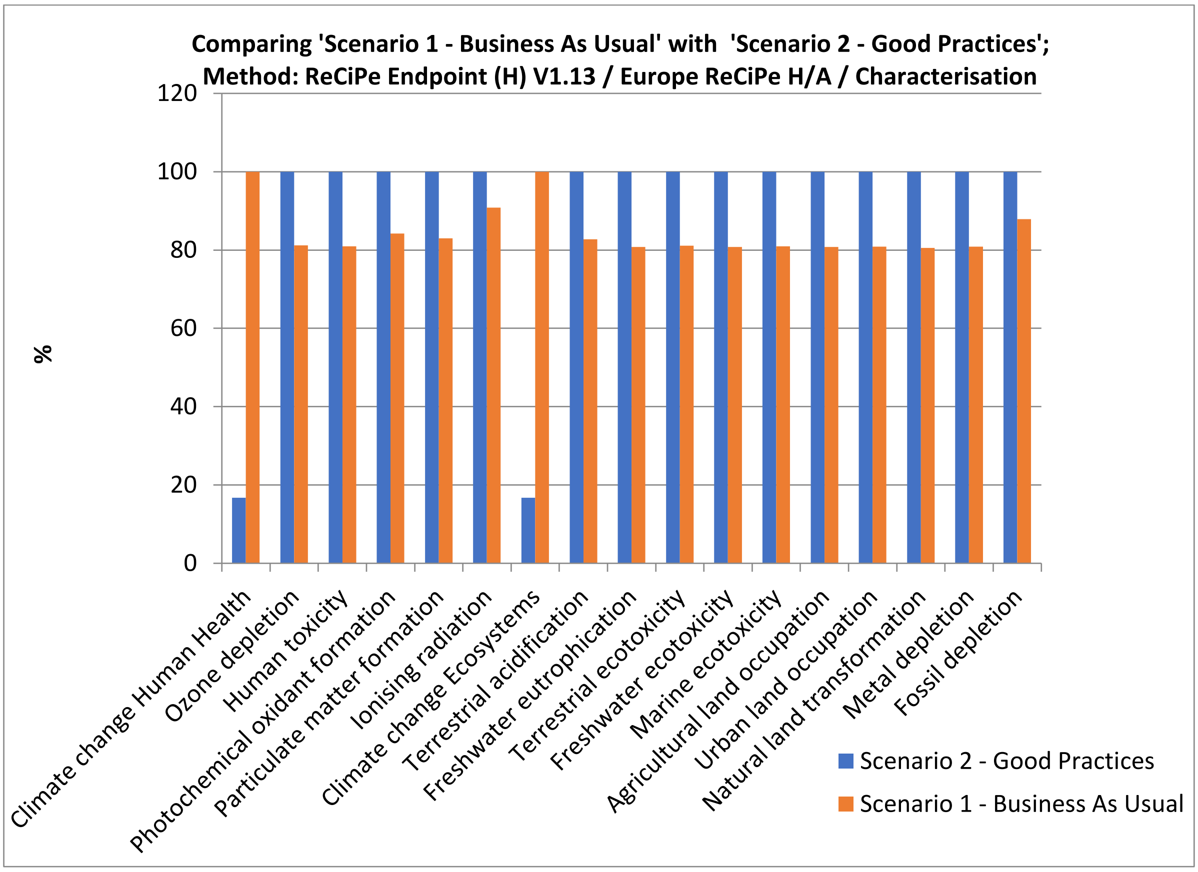


*Figure 2 Characterization of the results*

In relation to the previous graph, Figure 3 presents the comparison of the two analysed Scenarios regarding Damage Assessment in three categories: Human Health, Ecosystems and Resources. In the category of Human Health, Scenario 2 – Good Practices performed much better, but in the two remaining categories Scenario, 1 was slightly better.

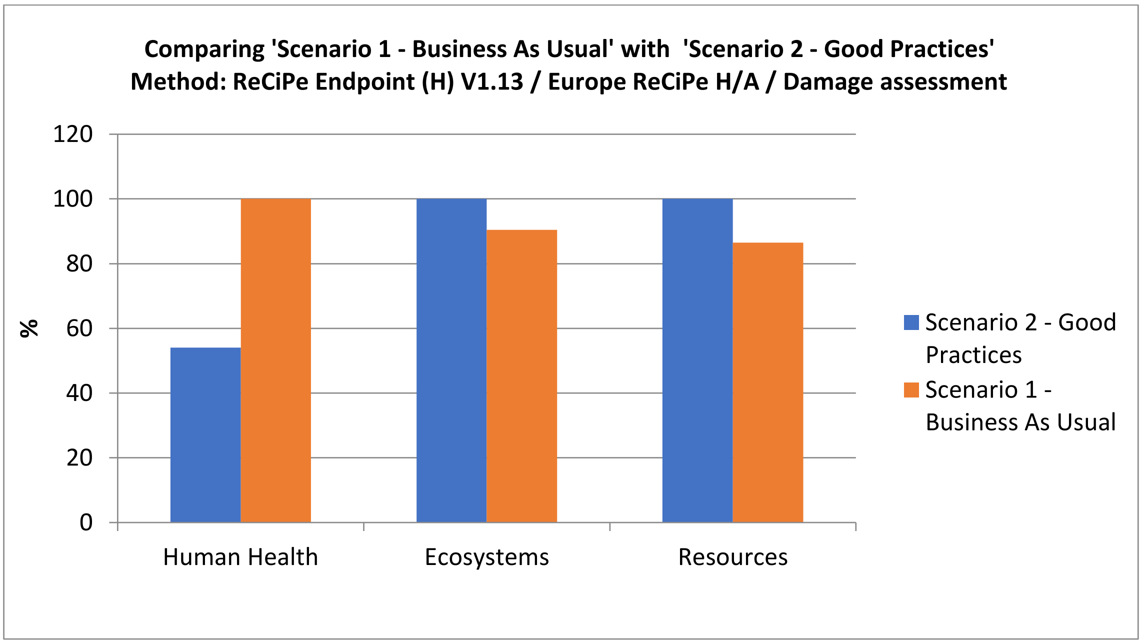


*Figure 3 Damage assessment*

Figure 4 presents the normalisation of Damage Assessment. Normalisation can be helpful in LCIA results, providing and communicating information on the relative significance of the impact category indicator results. This graph shows that in fact the impacts on Ecosystems are bigger than on Human Health or Resources.

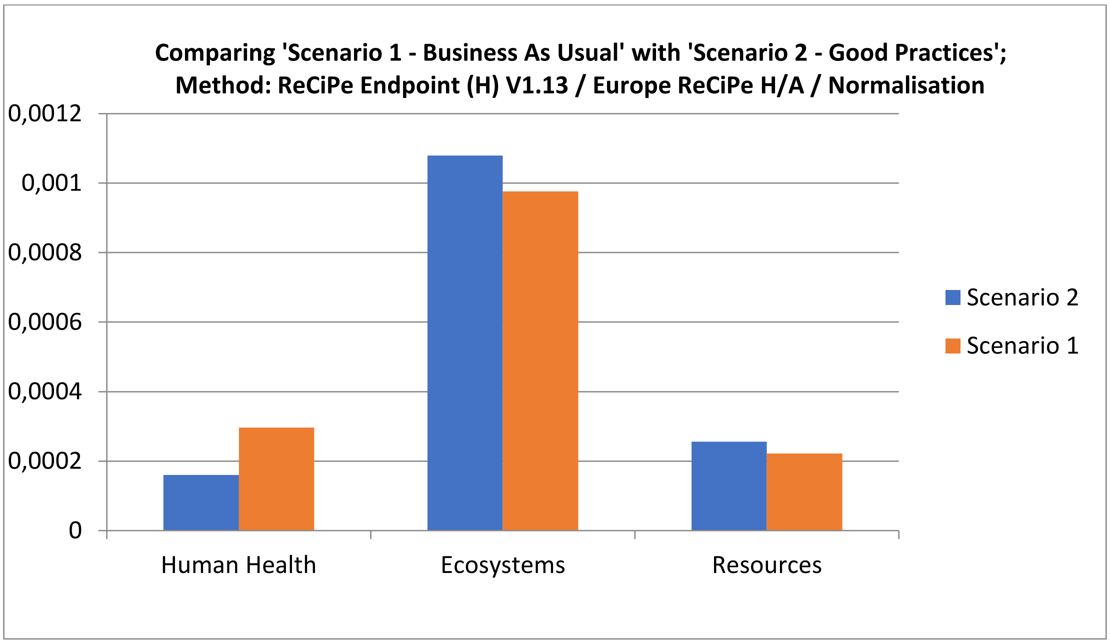


*Figure 4 Damage assessment normalisation*

Figure 5 shows that only the processes needed to obtain olives have a huge environmental impacts. Another input that has importance is electricity from the grid, but the rest is very small, and it has been neglected.

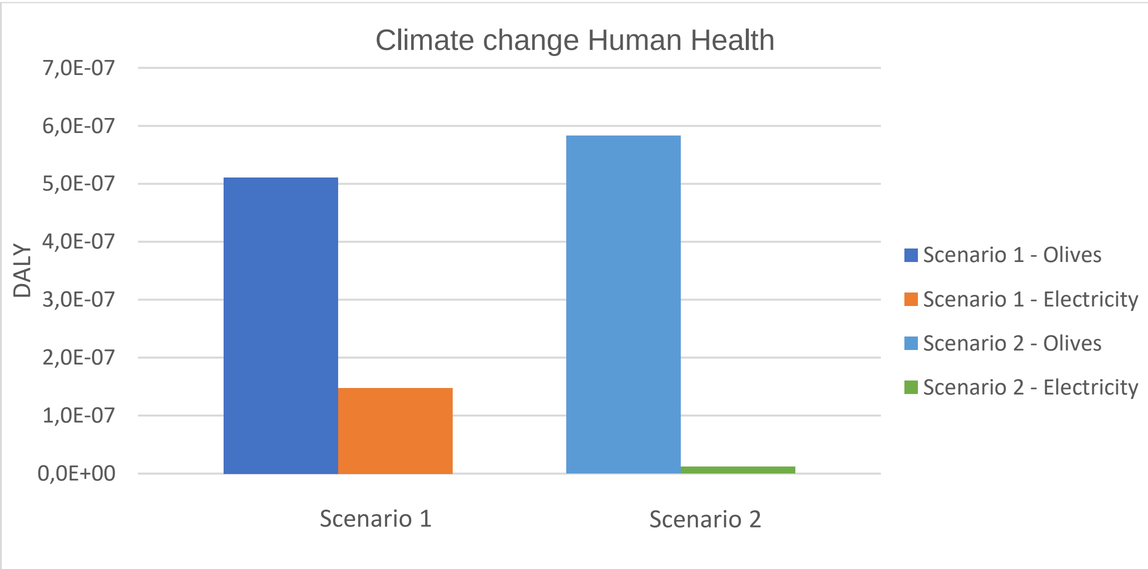


*Figure 5 Climate change Human Health*

### 3.1. Interpretation of the study

The goal of this Life Cycle Assessment was to analyse the olive oil production of the company from Alentejo region in Portugal and compare the standard method of olive oil manufacturing with a possible solution that includes energetic valorisation of waste, namely burning olive stones in a boiler to produce electricity. The main objective of this study was to check if implementing this solution will cause any major changes in terms of environmental impacts.

Due to the lack of relevant data, in this study, only the olive oil manufacturing phase was analysed, which makes it hard to compare this study to other studies in this area. However, as in other studies, it can be clearly noticed that the cultivation and harvesting of olives contribute the most to the environmental impact in every single impact category, in both scenarios. The industrial phase of olive oil production does not bring significant impacts on the environment; mainly it is electricity from the grid and water.

In the characterisation of the results, when the specific bar in the graph reaches 100%, it means that 100% of processes in this scenario contribute to the environmental impacts in a particular category.

When it comes to a comparison of the two scenarios, in most of the impact categories the proposed solution does not bring much improvement, it performed a little less than Business As Usual Scenario. However, when it comes to climate change specifically, it is visible in Figure 5 that the impacts related to the electricity from the gird were reduced, which is due to the own electricity production in the mill.

Since the functional unit was 1 l of olive oil, all the values obtained in the impact categories are very small. Therefore they are not very representative.

# 4. Conclusions and future developments

## 4.1. Conclusions about the proposed solution

Olive solid residues represent a great potential for the energy from biomass in the regions of olive oil production in Portugal. The calculations done within this work show that the proposed solution of burning olive stones in the steam biomass furnace to produce electricity is possible to implement in the facility like the analysed olive oil mill. However, because the solution requires a big reservoir of water available, this could be a potential problem, and it would need to be checked before implementing. On the other hand, the big amounts of water needed in the steam cycle to cool down the steam in the condenser can be recovered and put back in the storage pool, which makes this solution more viable.

A big disadvantage of this solution is the fact that constructing that kind of facility would take a lot of space. Basically, it is a small-scale power plant. It would have to be considered if the space needed is available in the facility of the olive oil mill. Following this concept of being a small-scale power plant, the electricity produced from biomass would have to be sold to the grid at the market price, which would generate income.

On the other hand, a great advantage of this scenario is the energetic valorisation of biomass, which is a by-product of olive oil production. Even though olive stones are already being used for the purpose of energy production, this work presents a different approach – generating electricity. Another advantage of using biomass is a reduction of $CO_2$ emissions, which is a common issue nowadays.

When it comes to the economic aspect, the investment needed for installation of the vapour cycle is huge (14 285 714 €). However, the pay off time of the investment depends on few factors, for example: if the company would be able to get the financial support from the community (in this case it would be around two years).

## 4.2. Conclusions from LCA

Life Cycle Assessment is a good approach to measure the environmental impacts associated with particular processes of the life cycle of the product. However, in this case, for the LCA to be more precise and representative, more specific data would be needed. The analyses showed some specific results, but for the LCA to be complete and to be able to see the impacts from the whole life cycle of olive oil, data from other stages would be needed too (cultivation and harvesting of olives, transport of olives to the mill, packaging, consumption etc.). In this work, some inputs and outputs used in the analysis were coming from the Ecoinvent database of SimaPro, which makes the analysis less detailed and less accurate.

Even with the little data available, it is possible to see that the highest environmental impacts are strictly related to the olives, not to the industrial phase of olive oil manufacturing. This trend also appears in other works that present the LCA of olive oil production.

Considering the data available for this study, it seems that the proposed solution brings worse effects on the environment than the standard method of olive oil manufacturing. However, the more detailed study would have to be performed to fully evaluate the real impacts related to both scenarios.

This study has proved that the LCA is a very demanding tool and the whole process is difficult. In this work, some assumptions had to be made before performing the analysis in order to complement the lack of data, while for the Life Cycle Assessment to be accurate, very detailed and good quality data is needed, preferably obtained from the interviews with people working in a specific facility.

## 4.3. Recommendations and possible further actions

Regarding the LCA itself, it would be recommended to get the detailed data of good quality, so the information provided in the software will demonstrate the real processes in the highest possible level. The most data possible should be obtained through visiting of the analysed facility and interviews with people involved in its operation.

First of all, the cycle presented in this work would need more research and development (more specific calculations of the cycle, and later implementing a pilot line) in order to check its performance in a real environment.

As it has been concluded previously, the proposed solution is possible to implement, but it requires a big reservoir of water. Even though the cooling water for the condenser is being stored again, the natural pool for water storing needs to be big enough. There are also possibilities to implement measures to catch and store rainwater or recirculate groundwater. The person responsible for implementation of the idea would have to consider all benefits and possible problems related to it.

If this solution were decided to be implemented, the more specific cost analysis would have to be done. The analysis included in this work is based on many assumptions that are results of research, and its purpose is to give a general overview of expected costs, but the situation would have to be deeply analysed, considering all factors, in order to estimate the real costs of implementing this solution.

As assumed in this case study, right now the mill operates for 5 months per year, but there is a possibility of buying olive stones from other, smaller producers in the region and running only the cycle for the whole year (excluding the time needed for the maintenance of the cycle). This way it would be possible to produce more electricity and sell it to the grid, which would make the investment pay off faster and would bring more profit.

Nowadays, governments in each country are promoting and supporting sustainability and all kinds of actions that involve the concept of Circular Economy. Maybe it would be possible to apply for subsidies and financial support from the government for that kind of installations for biomass burning.

## References

[1] "Leading the transition - Action plan for circular economy in Portugal: 2017-2020," November 2017. [Online]. Available: https://circulareconomy.europa.eu/platform/sites/default/files/strategy_-_portuguese_action_plan_paec_en_version_3.pdf. [Accessed 24 September 2018].

[2] C. Achillas, D. Aidonis, D. Folinas, V. Maslis and P. Tsarouhas, "Life Cycle Assessment of olive oil production in Greece," *Journal of Cleaner Production,* no. 93, pp. 75-83, 2015.

[3] L. Petti, P. A. Renzulli, R. Roma, A. K. Cerutti and R. Salomor, "Environmental impacts of olive oil production: a Life Cycle Assessment case study in the province of Messina (Sicily)," *Journal of Cleaner Production,* no. 28, pp. 88-100, 2012.

[4] V. Fitas da Cruz, B. Magalhães and C. Ascenço, "Alentejo Circular - Relatório de caracterização da economia circular," 2017. [Online]. Available: http://alentejocircular.uevora.pt/wp-content/uploads/2018/09/Relat%C3%B3rio-da-Caracteriza%C3%A7%C3%A3o-da-Economia-Circular.pdf. [Accessed 5 June 2018].

[5] Institute of Agriculture and Tourism Poreč Croatia, "Market of Olive Residues for Energy," 2008. [Online]. Available: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/report_on_best_practices_m.o.r.e._en.pdf. [Accessed 2 October 2018].