"Life Cycle Assessment (LCA) as a Decision Support Tool (DST) for the eco-production of olive oil"

TASK 4.3

Guidelines for the eco-production of olive oil

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Policy document for the improvement of the olive oil production cycle

The olive oil production stage

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Table of Contents

1 Introduction 4
2 Production of Olive Oil 5
3 Environmental pressures related to olive oil production 7
3.1 Introduction 7
3.2 Water Consumption 7
3.3 Energy Consumption 7
3.4 Emissions to air 7
3.5 Generation of wastewater 8
3.6 Generation of solid waste 9
4 Guidelines for the eco-production of olive oil 11
4.1 Introduction 11
4.2 Optimum consumption of water and energy 12
4.3 Minimization of emissions 17
4.4 General guidelines of good practice 20
4.5 Conclusions 23
5 Recommendations for policy initiatives 26
References 28

1 Introduction

This project aims at developing a decision support tool (DST) for the adoption of the appropriate processes throughout the life cycle of olive oil, in order to promote its eco-efficient production in three major olive oil producing areas: Voukolies (Greece), Lythrodontas (Cyprus) and Teruel (Spain). This aim will be achieved through Life Cycle Analysis, a technique for assessing the environmental aspects and potential impacts associated with a product over its life cycle.

The preceding three tasks of this project recorded and assessed the existing situation in regards to relevant legislation, current agricultural practices as well as the wider use of the LCA technique. They also identified the major sources of pollution throughout the whole lifecycle of the production of the olive oil.

The aim of this report is, based on the results of the previous tasks, to develop guidelines for the eco-production of olive oil, for all stages involved in this process. These guidelines will be communicated to the olive and olive oil producers in the regions under examination, in order to make a first step towards the improvement of the environmental performance of the actors involved in the olive oil production cycle.

The report focuses on the production of olive oil after reaching the oil production unit. A separate report is prepared referring to guidelines for the agriculture of olive oil.

The guidelines presented in this report derive from the conclusions the working team came up with from the implementation of the LCA in the three areas under examination as well as the experiences and research of the working team in the specific regions

The first section provides a brief description of the main environmental pressures related to the extraction of oil for the olives, based on the results of Task 3. These pressures include emissions to air, water and soils, as well as the consumption of energy and water.

Then the guidelines are presented addressing these environmental pressures and including techniques, which improve the environmental conditions related to the oil production. These guidelines refer to the pressures to all the environmental media as well as to the effective use of energy and water.

Finally a policy document giving recommendation for the promotion of the implementation of the guidelines is provided explaining the specific actions that need to be taken mainly by the central authorities in order to give motives for the development of environmentally sound olive oil production systems.

It is noted that in this report, the analyses and particularly the guidelines are not restricted in the production of virgin oil in mills, but it is expanded to oil refining, in order to be of use by the facilities carrying out refining activities.

2 Production of Olive Oil

The production process to extract olive oil from olives includes in general terms the following steps:

- Olive – crop storage. This may be made in:
  - Silos or in piles. The storage for big time intervals causes, due to their weight and bad ventilation, alterations, which are observed as temperature and oil acidity increase. Alteration becomes faster and more evident as the height of the stored mass is increased.
  - Baskets or perforated boxes, where the thickness of the crops layer should not exceed 30mm. The boxes are packed vertically in order to save space.
- Cleaning and Screening, which includes:
  - Cleaning of olive-crop from leaves
  - Removal of unusable oils olives
  - Screening based on olives quality
- Washing. This stage includes washing of olive-crop with clean water to remove dust, clay, etc.
- Milling. Various types of machinery or even combinations of equipment (complex grinding group) are used to mill the olive-crop. These machines are:
  - Olive mills with grind-stones
  - Other special grinding-mills
  - Roller-breakers
- Kneading. In this stage kneading of olive-pulp that results from milling, with hot water takes. With kneading the olive-cells are broken and the oil is released.
- Olive oil extraction, which occurs either by pressure (hydraulic press) or by centrifugation. From this stage olive oil and other liquids derive. The remaining solid olive mass constitutes the raw material in seed-oil facilities.
- Centrifugal separation. The received oil along with the other liquids go through centrifugal separation, where the final product (olive oil) is received. The common technique of centrifugal separation, which is used for the extraction of olive oil in Greece and Cyprus, is the three phase centrifugation (addition of water in decanters). Decanter products are: olive oil, olive core (containing 40-55% humidity) and other liquids. A new technique of centrifugal separation that recently began to be applied in olive presses is the 2-phase centrifugation (used in Spain), in which water is not added in the decanters. In this case, decanter products are: olive oil and olive core (containing 62-70% humidity). The advantage of this new technique is that no other wastewater is produced. The disadvantage is the high

humidity of the remaining olive core, which cannot be processed by conventional seed-oil facilities.

- Storage. The remaining olive core is temporarily stored and then it is transported to the seed-oil plant for further treatment.

The quantities of olive oil, olive core and liquids that result from the production process are 25, 40 and 35% respectively, over the initial weight of the clean olive-crop (after removing the leaves and soil residues).

However, most oils and fats are not yet suitable for consumption after their extraction and/or grinding. They contain impurities and undesirable components that must be removed, in order to produce high quality olive oil. Hence, the bulk oils undergo a treatment called refinement (purification).

In refinement installations, the raw materials used are olive oils (and other types of oil) in crude form. The products are refined edible olive oils but also margarines and cooking fats.

The production process can include the following stages:

- Filtering to remove non soluble impurities.
- Gum removal. Removal of gums that contain mainly phospholipids, and exploitation of the lecithin that is also contained in them.
- Neutralization. Aim of the neutralization process is to decrease the acidity of oils by removing the free fatty acids contained in them.
- Decolourization. Proper decolourizing agents are usually used to remove colorizing and other substances from the oils.
- De-odouring. Various substances with unpleasant odour and flavour are removed from the oils and the fats (unsaturated hydrocarbons, terpenes, aldehydes, etc)
- Wax removal. Aim of this process is to remove the waxes and it is applied mainly to oils that contain high percentages of waxes (e.g. the sunflower oil).
- Hydrogenation. The increase of the oil melting point makes it suitable for margarine production. Addition of hydrogen in unsaturated molecules is achieved in the presence of nickel as catalyst.

It should be noticed that not all of the above processes are used in a single refinement unit. The choice of the proper process and their combination depend on the raw materials used and the desirable final products.

3 Environmental pressures related to olive oil production

3.1 Introduction

This section describes the environmental pressures related to the production of high quality olive oil. These pressures refer mainly to the consumption of water and energy as well as to the emissions to air, water and soil.

3.2 Water Consumption

Water consumption in olive-oil mills depends on the kind and condition of olives, the extraction method (pressing or centrifugation), and the engineering practices followed. Significant differences are observed during olives washing. This process may consume water quantities from 0 to 50% of the initial weight of olives. Nevertheless, in most of the mills, large water consumption, for washing the crop, is avoided.

Large quantities of water are consumed in oil refining units. Water is used during several stages of the production process e.g. cooling and cleaning of the equipment and floors. Water consumption and wastewater production can be reduced considerably by recycling, as it will be described at a later section.

3.3 Energy Consumption

Consumption of energy is not considered a major issue with respect to olive oil production. The most common form of energy used in the sector installations is electricity. Consumption is analogous to the electric equipments used.

3.4 Emissions to air

In olive oil mills, the air emissions are not considered a problem. They mainly refer to the generation of odour, mainly due to improper storage of olives and oil.

On the other hand, air emissions are generated in the oil refining stage. More specifically, air emissions derive from:

- The combustion for the production of steam
- The deodorization process, during which volatile organic substances are released
- Cooling-condensers towers, drying of the neutral oil in the unit of neutralization, leakages from the expansion valves in the steam-production unit, which generate water vapors

- Wastewater treatment, which usually concerns the disposal of the wastewater in lagoons in order to evaporate. This technique generates odours and VOC emissions.

3.5 Generation of wastewater

The generation of wastewater constitutes the main environmental issues related to the production of olive oil. The wastewater present high pollution load (BOD_5, COD, suspended solids) and they also contain natural coloring substances, which are difficult to be removed by using conventional cleaning methods.

Wastewater is also produced mostly from the pressing process, centrifugal separation and cleaning. The wastewater produced has a dark color and characteristic odor.

The data on wastewater composition from olive-oil mills in Greece and Cyprus (using the 3-phase system) are presented in the following table.

Table 1: Composition of wastewater from olive oil mills in Greece and Cyprus

Parameter	Average value considered (mg/litre)
Total solids	63.550
Volatile solids	52.950
Total suspended solids	47.170
Volatile suspended solids	19.000
BOD	47.500
COD	116.500
Phenols	5.925
Volatile phenols	3.100
Total Nitrogen	10.000
Phosphorus	415
Potassium	1.950
Calcium	398,5
Magnesium	225
Sodium	470

Parameter	Average value considered (mg/litre)
Silicon	18
Sulphur	63
Chlorine	124
Lead	0,54
Iron	26,5
Copper	3,5
Manganese	6,5
Zinc	6,7
Nickel	6,2
Chromium	9
Cadmium	8

Wastewater originates also from most of the processes carried out in a refinery. Wastewater of high organic load is discharged from the neutralization process, during the washing of the neutralized oil in order to separate additional oil quantities from the soap mass and from the neutralization reaction wastewater.

Wastewater is also generated from:

- The gravity condensers (deodorization process). This wastewater may be recycled.
- The steam generation unit (brine, cleaning water from the softening column). These liquid wastes contain low organic load.
- Floor and machinery cleaning.
- Cooling towers. This wastewater stream contains only inorganic load.

Finally, there may be oil spills and leaks during unloading and storage of raw materials as well as during storage of final products.

3.6 Generation of solid waste

The only solid waste generated refers to leaves from the cleaning stage. In the refinement units the generation of solid waste concerns the:

- Dregs, solid remains, inactive filtering agent from filtering

- Gum or lecithin (by-products) from de-gumming
- Soap cake with high humidity content from neutralization
- Exhausted decolorizing agents from decolorizing
- Fatty substances from deodorizing
- Waxes (by-products) from de-waxing and margarines removal
- Diatomic soil from margarines removal
- Exhausted catalysts and filtering agents from the stage of oil hydrogenation
- Solid wastes (bottles, caps, papers) from packaging

Finally, solid waste, namely sludge, is generated during the management of the wastewater, either in lagoons or a more comprehensive wastewater treatment practice. Particularly if wastewater treatment is available (this is not the case for the olive oil mills in Greece and Cyprus), the solid waste sludge form grinding, sediments, crust from the coagulation – clarifying process and the surplus of biomass from the clarifiers.

4 Guidelines for the eco-production of olive oil

4.1 Introduction

In this section the guidelines for the environmentally friendly production of oil for the collected olives are presented. These guidelines aim at the minimization of the environmental impacts related to the production of olive oil. The guidelines are tailored to the needs of the areas under examination and refer to the following:

- Effective use of water and energy
- Minimization of air emissions, solid waste and wastewater generation
- General guidelines of good practices

It is noted that the following guidelines are not restricted to the olive oil production in mills, which is within the scope of the project, but are extended to cover other oil process such as oil refining (deodorization, decolourization, etc)

In reference to Environmental Good Practices, it is expected to achieve some specific objectives, through concrete, clear and easy recommendations and its application on industry. These specific objectives are shown hereafter:

Aspect	**Objectives**
ENERGY	Reduce energetic consumption Performance Optimization Combustion processes' improvement
WASTE	Minimize waste Appropiate waste management: storage, identification, remove...
ATMOSPHERE	Minimize chemical emissions Minimize noise emissions
LIQUID	Minimize spills Treatment improvement
SOIL	Avoid soil pollution

The application of the recommendations collected in a Environmental Good Practices Guide, should be the first step for an organization in order to achieve, in a easy way, an environmental improvement and its benefit.

Some of the revised documentation and guides of good practices applied in oil mill are specially recommended:

4.2 Optimum consumption of water and energy

4.2.1 Olive oil production

There exist considerable opportunities to reduce water consumption and therefore wastewater production in vegetable oil and fats refining industry.

This may be achieved with the production of olive oil by centrifugation instead of hydraulic presses. Two stage centrifugation, which is applied in Spain and not in Greece and Cyprus, is the best solution (water saving, reduction of the wastes' volume) but the olive kernel produced contains high amounts of humidity and cannot be used by conventional kernel oil mills. Two-stage centrifugation is proposed for new installations but the impact of high humidity must also be taken into account. Also the consumption of water should be controlled during the washing of the olives. The use, wherever possible, of closed recycling cleaning system (C.I.P.) is also promoted. The application of such a system allows energy savings, as well.

In addition, the design and optimization of the plant should be based on energy recovery, by-product recycling or reuse, water recycling and minimization of the produced waste volume.

The use of large amounts of water is a characteristic of this type of industry and saving is the main objective. However, health requirements restrict the use of large quantities of recycled water. In any case, olive purification, with recycled water should be applied. Proper and rational management of water (analysis of necessities, management of water cooling circuits, water for cleaning the floor and equipment, recycling, water management in the procedures) is possible to lead to a significant reduction of water requirements and, thus, to the reduction of the volume and load of liquid wastes. The most common measures for saving water are:

- Adaptation of good operation practices. Water management is improved by upgrading the mechanical equipment, installing automatic control systems for pumping, storing and transportation of water, training personnel, adopting hygiene practices, adopting adequate cleaning procedures, adopting procedures for equipment maintenance, measuring water consumption and detecting/fixing leaks in water piping networks.
- Recycle-Reuse of cleaning water. Collection and reuse of water used in the system of equipment cleaning.
- Recycling/Reuse of water contained in the boiler for other usage within installation.
- Waterjet cleaning - Segregated collection of polluted water, and send them to a pool - Segregate clean rain water.
- Always wash fruit on a closed circuit.
- Place a water meter on the water entrance in order to register consumption.
- Control water quality of the washing circuit, in order to replace it only when necessary.

- Send sewage water to evaporation pools.
- If there are several water sources, use the poorest (quality) one for this step.

With respect to the consumption of energy, its efficient and rational management of energy (necessities' analysis, combustion improvement, essential insulation of thermal surfaces, use of energy saving equipment, automations in the processes, improvement in exploiting thermal content of exhaust gases) is possible to bring significant reduction in the requirements of both energy and emissions of exhausted gases. The efficiency improvement of energy and the economic exploitation of energy in new and existing installations offer opportunities for energy saving while at the same time presents economic benefits. Many of the technical choices for energy saving require a quite small investment and can be easily applied. In some cases even small changes in organizing can bring significant energy savings and present environmental benefits and economic profits. Furthermore, the measures taken for saving energy have often short time payback. The usual measures applied for energy saving (including the olive processing stages) are:

- Adaptation of Practices for Efficient Operation. As to energy saving, it mainly concerns upgrading of the mechanical equipment and automatic control systems in the stages of production and transferring of energy, personnel training, cleaning procedures, maintenance procedures, measurement of energy consumption, and detection/fixing of leaks in the boiler's piping network, cooling systems and thermal energy transferring.
- Upgrading of the mechanical equipment.
- Improving the Efficiency of Steam-boilers. The thermal energy contained in fuels should be efficiently exploited. Therefore, when combustion procedures are carried out in order to cover energy requirement of a physical process or an installation, highly efficient combustion should be achieved by means of exploitation, if possible, of the thermal energy contained in the exhaust gases.
- Heat recovery from exhaust gases. Exhaust gases are basically at high temperature (over 200-250 degrees) and, is usually possible to be used for warming the air feed of combustion via an air to air heat exchanger.
- Heat recovery and Reuse from steam condensation. The exploitation of steam condensates as feed liquid of the steam-boilers, apart from the energy saving, contributes to water saving as well, causing significant economic benefits.
- Minimization of Thermal Losses. The use of insulation in equipment parts where liquids of high temperature are flowing is possible to minimize heat losses and to significantly improve energy efficiency.
- Turn engines off while vehicles are waiting for unloading

The proposals for energy management and transport issues are summarized below

PROBLEM OR IMPACT	PROPOSAL OR GOOD PRACTICE	EXPECTED IMPROVEMENT
ELECTRIC AND ENERGETIC CONSUMPTION	Realization of **ENERGETIC EFFICIENCE AUDITS** in order to detect improvements and act in the next ways: - Electric fares optimization. - Frequency inverter utilization - Lighting consumption reduction - Heat recovery from boiler smoke - Change to natural gas or others - Evaporative condensators installation - Boiler purgative recovery - Condensations recovery - Boilers' combustion parameters adjustment and control - Control of losses and leaks - Cogeneration installation - Old machinery substitution, looking for more energetically efficient machines - Concentrates and ground effluents preheating - Efficient drying - Others	- Consumption reduction
	Installation of **AUTOMATIC PROCESS CONTROL** - Mixing temperature control - Temperature and flow control for decanter addition water	- Consumption reduction - Quality risks reduction

PROBLEM OR IMPACT	PROPOSAL OR "GOOD PRACTICE"	EXPECTED IMPROVEMENT
TRANSPORT OF POMACE	Pomace's **EFFICIENT DRYING** using solar thermal energy	Reduction of the weight to transport, and therefore less transportation related impact.
	Utilization of Pomace as **BIOMASS** in order to produce electricity or heat.	- Transport elimination - Electricity and heat self - production. - Reduction or elimination of electricity an fossil fuels buying.
	Utilization of Pomace as **COMPOST** material	- Transport elimination - Elimination of industrial fertilizers (IMPACT DETECTED ON AGRICULTURAL PHASE)
OTHER TRANSPORTS	Creation of **Buying Consortium** among olive mills for gases and fossil fuels acquisition.	- Avoid small deliveries, so transport impacts are minimized.

The adoption of specific proposals or good practices, except those referred to electric energy consumption, cannot be taken on a particular way for each olive mill. Moreover, collaboration among different olive mills would be required through consortiums or associations.

This would not only require viability studies, furthermore it should include awareness for the environment and information for farmers, agricultural technicians and olive mills owners

The technical and economical viability of the proposals is guaranteed by several technical studies, and although everything seems to be indicative of a clear environmental improve, to be rigorous specific comparative LCA studies should been done in order to get enough information for the decision taking. (For example, comparative LCA Chemical Fertilizers vs. Organic Compost)

4.2.2 Water saving during oil refining stages

Measures for olive oil processing include:

- Recycling of the water used in barometric condensers (deodorization unit). Before recycling, the water is passed through an oil-separator and then cooled.

Regarding the cooling stage prior to re-circulation, there are two alternatives:

The water is collected in a tank and then directed to a cooling tower, then it re-circulates to the condensers. Alternatively, the water is cooled in a heat exchanger by the use of a secondary cooling circuit. The water circulating within the latter is led to a cooling tower and then recycled to the secondary cooling system (indirect cooling). Although the first system is often applied, it has a significant drawback: When the plant is shut down, the cooling towers operation is interrupted and as the effluents are not aerated, degradation of the organic substances contained in these effluents begins. This results in the development of secondary odour releases from the collection tank. The above disadvantage can be eliminated by implementing a “secondary” cooling system (double circulation). The application of this innovative system not only allows water savings, but also prevents odours releases.

- Substitution of the water-operating barometric condensers with steam-operating barometric condensers and a steam condensation system in the deodorization unit.
- Re-circulation of all steam condensates into the steam-boiler. Prior to recirculation, an amount of steam produced should be removed.
- Re-circulation of the cooling water, which is used at the hydrogenation process.
- Cooling and recycling of cooling waters of all machinery (e.g. heat exchangers).
- Use, wherever possible, closed recycling cleaning system (C.I.P.). The application of such a system allows energy savings, as well.

4.3 Minimization of emissions

4.3.1 Air emissions

The air emissions mainly refer to odour releases. There releases may be reduced via:

- The storage of olives in appropriate areas (e.g. in silos), but not for a long period of time
- Storage of the produced olive-kernels in covered areas with adequate ventilation until their shipment to kernel-oil mills

Prevention of odorous substances release from the condensers during the oli refining, in no-working periods, is achieved by implementing an indirect cooling system. Odors produced during the deodorization process can be successfully controlled by a water-scrubber/ barometric condenser system.

Other measures that may be applied to reduce the air emissions related to combustion is the optimization of the operating conditions, the regular maintenance of equipment, the continuous monitoring of machinery efficiency and the substitution of diesel oil by LNG.

4.3.2 Wastewater

The recommended system for the treatment of wastewater includes neutralization combined with coagulation (addition of lime) and sedimentation. The treated water may be used for irrigation of olive trees.

An alternative solution for sedimentation and digestion, without equipment for the removal of the sludge, is the use of IMHOFF tanks, although it has a relatively higher cost.

After the treatment mentioned above, waste still contain high organic load. Several methods have been developed for their final disposal but they are in a pilot stage and they have not been widely applied yet. Such methods are: irrigation of olive-plantations, condensation, anaerobic digestion combined with biogas production (methane production 50-60%). In this later method, the generated methane can be recovered and used for energy production.

All wastewater from oil refining may passed through an oil-separator. Biological treatment usually follows for the reduction of BOD, suspended solids and other pollution parameters. Separation of waste streams may be appropriate in certain cases. In oil and fat refining units it is recommended to separate the wastewater of high pollution load from wastewater with low pollution load.

In particular, wastewater of high organic load is usually, and most cost-effectively treated by using the following procedure: They are collected in a tank and their pH is adjusted by adding $Ca(OH)_2$. Then, they are directed to another tank, where they are left to settle for several days. The solid impurities precipitate while, partial anaerobic decomposition of the biodegradable organic load takes place. After this, there are two alternatives:

a) They are further treated by chemical coagulation-precipitation and discharged to a sewage system, *or*

b) They are directed to open lagoons, where they undergo physical biological treatment (aerobic or anaerobic), while their volume is significantly reduced through physical evaporation. This specific method is simple, cost-effective and efficient, but it may require excessive land use.

The treatment of wastewater from barometric condensers (low organic load) depends on the circulation system used in the deodorization unit:

- When *a single circulation system* is used, the treatment may include the following stages:
    - Oil-separation by gravity
    - Dissolved Air Flotation (DAF)
    - Aeration in cooling towers
    - Collection tank
- Recycling to the barometric condensers
- When a double circulation system is used, the treatment may include the following stages:
    - Wastewater from barometric condensers:
        - Oil-separation by gravity
        - Cooling in heat exchangers (with “secondary” cooling water)
        - Recycling into the barometric condensers
- “Secondary” cooling water (heat exchangers)
    - Aeration in cooling towers
    - Collection tank
    - Re-circulation into the heat exchangers

With respect to the oil spills they should be treated by using woodchips, which can then be disposed of as solid waste.

4.3.3 Solid waste

<u>Olive oil production</u>

Waste treatment to recover useful byproducts (natural coloring substances, proteins). The kernels should be transferred to units for the production of kernel oil.

Also, the frequency and volume of waste discharge from centrifuges should be in line with the specifications of the manufacturers of the equipment.

Storage of all waste susceptible of being dispersed by wind or water in closed and opened places.

Other proposals include:

- Application for Small Producers Registry
- Characterization and quantification of all products produced in the facilities.
- Registration of all waste produced and given to third parts.
- Segregation of waste by their characteristics.
- Waste giving to authorized managers, prioritizing those ones who offer recycling processes
- Storage of waste properly packed and labelled in safe places
- Avoid incineration of dangerous waste in the boiler.
- Develop or Collaborate in studies about boiler ashes and evaporation pools' mud valorization as agricultural land amendment.

Oil refining

Most of the by-products and solid wastes produced in vegetable oil and fat refining industries can be used as raw materials in several other industries. The following are recommended:

- Lecithin (by-product). It can be used in food industry, pharmaceuticals, animal food production, etc.
- Soaps. They can be utilized in soap production industry, or they can be treated with dense sulfuric acid solution. The product of this reaction is a free fatty acids (FFA) that can be used either as raw materials in other industries or as bio fuels.
- Collection of fatty compounds and usage as raw materials in soap making industries
- Spent decolorizing agents. They can be utilized in cement production or they can be used as additives from the animal food production industries
- Nickel catalyst: It can be recycled (in the hydrogenation unit) until its activity is substantially reduced. The spent catalyst can then be directed to a nickel-recovering plant.
- Bottles, papers, paperboards and other packing materials. They can also be utilized in other industries (mainly paper recycling industries).

4.4 General guidelines of good practice

One of the easier and economic ways to reduce pollution at source is the application of good operating practices. World wide, many companies apply such environmental policies that include personnel training, hygiene, innovative cleaning procedures, water and power consumption reduction, equipment maintenance practices and leakage detection. It is noticed that auditing techniques should be applied to ensure proper application of the above. Auditing should be practiced by a highly specialized team of either employees of the installation (internal audit-that occurs in frequent time intervals) or other specialists (third party – external audit that occurs less frequently). The usual practices of efficient organization that a unit may apply are:

- Acceptance of an administrative plan. Good operating practices start with the acceptance of an administrative plan by the executives of the enterprise and the comprehension of the necessity to implement pollution prevention practices by all employees. Without joint effort, adoption of environmental responsibility in the administration level, all-embracing organizing and management of the company, reduction in the source may not be successful.
- Upgrading of mechanical equipment. By upgrading the primary mechanical equipment, more efficient control can be achieved, production efficiency is improved and the losses in both storage/production activities are reduced.
- Measurement and control of water and energy consumption. The effort to reduce consumption of water or energy is always based on the evaluation of the existing situation of water and energy consumption for which appropriate consumption measurements are required. These measurements are compared with the average indexes of water and energy consumption in similar installations. This comparison can reveal the appropriate actions that must be taken by the company in order to reduce water and energy consumption by marginal changes in both operating practices and the machinery used.
- Maintenance of the mechanical equipment. Maintenance program should have two objectives: Preventive maintenance (according to the recommendations of the equipment manufacturer), fixing of possible equipment damages but also their prevention. The equipment of an installation should be checked and cleaned regularly to ensure its efficient operation. In case of a damage or a failure, it should be fixed immediately. Moreover, the documentation of checks, repairs, cleanings and failures of the equipment, will contribute to the reduction of both the possibility for a future interruption of operation and accidental releases such as leakages or emissions. Sufficient maintenance of the mechanical equipment has both positive economic effects (less interruptions) and environmental effects for both all storing/productive activities and auxiliary supplies (water and energy).
- Prevention and management of leakages and fugitive escapes. The avoidance of leakage is of primary importance for preventing pollution. Leaks and fugitive escapes can be avoided by installing appropriate equipment to prevent leaks and escapes. A leakage detection system and the implementation of preventive maintenance are considered to be helpful. Efficient application of systems that

prevent and manage leakages has both positive economic effects (less losses) and positive environmental effects for both all storing/productive activities and auxiliary supplies (water and energy).

The following general measures, may also have as result the reduction of environmental pressures as well as the optimization of the production process achieving high rates of efficiency at lower cost and consumption of resources:

- Personnel training on pollution prevention and control. The personnel should be aware of the main issues related to the environmental performance of the installation and be educated on how to reduce the use of energy and water. The application of a training program for the personnel is of primary importance for the successful reduction of the pollution in source. The employees should be trained to operate safely the equipment, the materials and wastes. Training is also required for leaks/escapes detection and cleaning.
- Assignment of responsibility for the monitoring of all pollution control systems performance. A person responsible for the monitoring of the environmental performance of the installation should be assigned. This person will be responsible for checking the good operation of the unit and identify potential sources of unexpected pollution
- Monitoring of the volume and quality of solid waste and wastewater. This data should be stored at appropriate files (preferably electronic files) and be easily retrieved whenever it is necessary
- Control and maintenance of the equipment, according to the specifications of the producer of the equipment
- Detection and prevention of leakages, especially to wastewater spills, which may have significant impacts to the soil, surface and groundwater
- Tree plantation for the reduction of noise and aerthetic nuisance

The application of the recommendations collected in an Environmental Good Practices Guide, should be the first step for an organization in order to achieve, in a easy way, an environmental improvement and its benefit.

The best way to manage properly an olive mill form an environmental point of view, is to implement an **ENVIRONMENTAL MANAGEMENT SYSTEM**. This is the best “Good Practice” that can be recommended, because an **Environmental Management System** on an olive mill guarantees, among others:

Legislative fulfilment on environmental matters
Objectives, Indicators and Environmental Programs establishment, focused to minimize: - Water or Soil spills - Atmospheric emissions - Waste generation - Energy consumption - Material consumption - Water consumption
Proper management and treatment of the generated waste through authorized managers
Worker training and motivation on environmental matters
Environmental Emergency Plan existence
Proper maintenance of facilities, minimizing leaks

The environmental management systems are optional practical tools that may be implemented by olive oil production companies. Such systems consider environmental implications as essential parameters of every activity in the installation. They assist enterprises to identify, assess and manage the environmental implications of their activities, and practically help companies to:

- Reduce the consumption of water and energy
- Reduce their air emissions, waste and wastewater generation
- Gain a comparative competitive advantage
- Establish a system of continuous environmental improvement
- Exhibit compliance with legislation
- Improve their public image. This is particularly important in the case of Crete, where the management of the wastewater has become a problem of national level, with severe implications in the relationship of Greece with the EC.

There are several Environmental Management standards, but the most popular is the ISO 14.001 standard. This standard belongs to the ISO 14.000 standards family, which includes the LCA 14.040 standard used in this study.

At a European level we can base our Environmental Management System on (CE) 761/2001 regulation, Eco-Management and Audit Scheme (EMAS)

All of them have a voluntary basis and, as a complementary fulfilment guarantee, they have a certificate and they are subjected to periodical external audits by an independent third part.

In reference to Environmental Good Practices, it is expected to achieve some specific objectives, through concrete, clear and easy recommendations and its application on industry. These specific objectives are shown hereafter:

Aspect	Objectives
ENERGY	Reduce energetic consumption Performance Optimization Combustion processes' improvement
WASTE	Minimize waste Appropiate waste management: storage, identification, remove...
ATMOSPHERE	Minimize chemical emissions Minimize noise emissions
LIQUID	Minimize spills Treatment improvement
SOIL	Avoid soil pollution

4.5 Conclusions

Based on the overall conclusions for the interpretation, previous environmental studies, ECOIL results and many other papers, it is argued that drastic changes are needed to obtain the environmental production of olive oil.

4.5.1 Short term

- Promote the use of vertical centrifuge water as land fertilizer in olive grove
- Implement environmental management systems in the oil mills (ISO 14.001, EMAS, EKOSCAN…)
- Energy Auditing in Oil Mills
- Develop an association for buying energy carriers for the local industries
- Automatization of processes, with previous energy and mass analysis (LCA and other methodologies)
- Promote efficient pomace drying by thermal solar energy to minimize environmental loads of transportation.

4.5.2 Medium term

Pomace management

Pomace has a high environmental impact for our industrial phase case study due to transportation to pomace to further oil extraction. Extraction of refined olive oil from two phase system is more difficult than in 3 phase ones and also, oil from worse quality is obtained. Furthermore, olive oil cannot compete with other vegetable oils in market. Also, this way of pomace management is an easy way to transfer problem to other point. Final management of this subproduct will pollute more other local area but, definitely, will create environmental impact in Almazara del Ebro. Pomace won't be seen anymore there, but still being a problem. Atmospheric pollution does not respect countries boundaries or natural areas.

The best that can be done with pomace is compost, that applied to the soil will recover most of nutrients extracted when gathering the olives. Oil is almost 100% formed from carbohydrates and thus, does not has macronutrients among its composition. Oil is CO2 shaped by sun and olive tree, and cycle of nutrients of this agro-industrial system is very easy to close.

However, due to practical limitations, LCA and other studies must be made to search for benefit of this measure in environmental and economic terms. Contact with oil mills that are already composting their residues is compulsory to obtain a technical support when performing this change.

4.5.3 Long term

Integral Management of Olive Oil.

The eco-efficient oil mills and organic farmers must be one when managing olive oil production:

- Compost production will involve many local actors: pomace (oil mill), straw (non olive oil farmers), sheep dung (livestock farmers)
- There should be a production of "green energy" for other industries based in extra energy coming from waste generated in the process: pruning residues, husk and other wastes.
- Some local production of biodiesel for tractor running can be planned

Agrarian co-operation

Promote corporatism of oil producers to share machinery (mainly wastewater treatment plants) and other goods.

Local Economy: Local consumption vs. distribution of goods

Local production of goods allows consumer to have a closer contact to oil producers and easily trace back through production chain. Furthermore, money remains for local and rural economies, usually exporting nutrients in form of food at considerably low prices –and that haven't change to much since a long time- and buying everyday more expensive chemical inputs. Added value for produced goods remains in area, allowing people carrying several activities to satisfy population needs.

This will lead to minimize environmental impacts, promote local good quality foodstuffs and enhance local investment.

5 Recommendations for policy initiatives

The following section indicates the basic policy initiatives that are recommended in order to promote the sustainable and environmental friendly production of olive oil. These proposals are based on the general concepts that derived from the analysis of the life cycle of the olive oil production and particularly the processing of the olives in the mills.

It is noted that the basic environmental issues related to the olive processing to produce olive oil refer to the generation of the wastewater fraction in the 3 phase centrifugal separation (applied in Greece and Cyprus). Other issues relate to the consumption of energy and water, while for the 2 phase centrifugal separation (applied in Spain), the main concern is to manage the humid by-product.

Fines have already been imposed to Greece in relation to the inadequate management of the wastewater, which is usually uncontrollably dumped.

However, the sustainable management of this fraction requires significant investments and high operation costs, which cannot be bear by the oil producers.

The governments should allocate a small amount of the funds coming from EU sources for the supporting of the development of the necessary infrastructures.

A policy motivating the implementation of sustainable practices in olive oil production would reduce the environmental burden linked to the oil production. The tools to develop such policy may include:

- Development of a strategic plan (national, regional or prefectural)) for the management of the wastewater from olive oil production, describing specific targets and actions to be taken
- Co-funding of the necessary infrastructures from EU funds. Co-funding may reach up to 50 – 70%. The infrastructure may include either construction of wastewater treatment plants or substitution of 3 phase systems with 2phase systems
- Tax releases, when environmental practices are implemented
- Funding of research and pilot projects for the management of wastewater (3-phase systems) or the management of humid by-products (2-phase systems)
- Imposition of taxes in the production of specific environmental pressures
- Strict control and monitoring of the performance of the olive oil mills – imposition of fines
- Establishment of financial motives for the implementation of environmental management systems or Eco-label products - Programmes to implement sustainability strategies for olive oil production could be developed by the competent Authorities, including targeted funding/subside for:

  - Associations of oil producers who employ a technical advisor for developing and pursuing more sustainable practices.
  - Grant-aid for investments in environmental improvements (e.g. machinery for changing to non- tillage systems).
  - Economic diversification, improved production quality and labelling schemes incorporating environmental criteria.
- Promotion of collective wastewater management and not separate management (neighborhooding mills could treat their waste together)
- Finally the raising of awareness and training of the olive mills operators is particularly significant, in terms of environmental performance improvement. The aim of the campaigns should be to inform the olive mills operators about the capabilities to improve their performance and the opportunities to receiving funding for the necessary infrastructures. The content of the dissemination campaigns and of the training courses must be adapted to:
  - Age, years of working experience and level of education of the operators
  - Main employment of the operators (full - time or part – time olive tree farmers)
  - Size of olive mills
  - Existing awareness and interesting level of the operators in environmental issues
  - Current mode of getting information (personal observations and experience, etc.)

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