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ORGANIC WASTE MANAGEMENT FOR ENERGY PRODUCTION IN CRETE

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Master in Science (MSc)

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Dedicated to my family

Andreas, Basiliki, Anna, Georgios, Vaggelis and Katerina

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published work of others has been acknowledged in the text and a list of references is given.

Signed: ____

Date: May 21, 2021

ABSTRACT

Olive oil production is one of the most important industries in the Mediterranean region and especially in Greece, that belongs to the top three countries with the biggest olive oil production alongside Spain and Italy. However, olive oil production also results in organic waste which, up until now, is disposed into the ecosystem and has contributed towards pollution of the environment at a significant level. Especially in Crete, a considerable amount of olive oil mill waste, ends up in rivers and the sea. The above mentioned organic waste, due to its heavy load of chemical composition, can be used as a raw material for biogas production. The main purpose of this master thesis, is not to examine the magnitude of the environmental pollution but to provide an alternative olive oil waste management solution by taking advantage of the existing process of anaerobic digestion of organic waste to biogas.

Emphasis will be given on the island of Crete, as olive oil production is considered to be the main agricultural activity. This research will try to tackle two serious problems of the island, the organic waste management and the energy supply autonomy. The possibility for an alternative combination that provides a solution to both the aforementioned problems will be examined. On top of that, considering the inevitable exhaustion of fossil fuels and the recent market trend of switching to renewable sources investments, a detailed business plan will be developed, whose all parameters will be examined in order for this solution to provide realistic and profitable opportunities for business investments on the island. For this reason, each stage and factor will be thoroughly analyzed, starting with the production of olive mill waste volume on the island. Also, the biofuel production capabilities will be assessed, the market demand, the potential profits and also the initial capital and investments that this project will require. As far as the latter is concerned, factors such as the legal frame and potential state support or European funding will be also considered. In addition, the necessary equipment and technologies will also be explored. Finally, an attempt will be made to generalize the conclusions and indicate how applicable the latter are into the broader range of Mediterranean olive oil production countries.

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There are many people who have helped a lot throughout this work. First, I would like to thank my Professor, Dr. Stelios Tsafarakis for his advice and the excellent cooperation that we had. Furthermore, I owe a deep sense of gratitude to my sister Anna Saridaki for her constant support and encouragement. Her contribution was vital in completing this thesis. Also, I would like to thank my dear friend Apostolis Panigirakis for his suggestions and support. In addition, I am grateful to my life partner Katerina Skillo and I could not thank her enough for her understanding, patience and encouragement. Finally, I would like to express my foremost gratitude to my parents for their support during my work and their everyday advice during my life that guided me through this way. Without them, this thesis would not have been possible.

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LIST OF ACRONYMS

ACOM	Association of Cretan Olive Municipalities
AD	Anaerobic Digestion
BOD	Biochemical Oxygen Demand
CHP	Combined Heat and Power
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
EBBR	Expanded Bed Biofilm Reactors
EU	European Union
FBR	Fluidized Bed Reactors
FIT	Feed-In Tariff
GPD	Gross Domestic Product
HVO	Hydrotreated Vegetable Oil
IRR	Internal Rate of Return
Mtoe	Million tons of oil equivalent
MW	Megawatt
NPV	Net Present Value
OMSW	Olive Mill Solid Wastes
OMW	Olive Mill Wastes
OMWW	Olive Mill Wastewater
OOMW	Olive Oil Mill Wastes
RES	Renewable Energy Sources
SHP	Small-hydro powered plants
TJs	Terajoules
UASB	Up flow Anaerobic Sludge Blanket

1 INTRODUCTION

Modern society is plagued with many problems that endangers the social well-fare. One of the most important issue that challenges humanity in general, is the energy supply problem. In recent times, the energy industry is facing a rapid transformation as energy demand is increasingly raising due to the modern needs of individuals and also by the rapid industrialization of developing countries. More specific, it is estimated that daily, at a global level, more than a million terajoules (TJs) of energy are consumed, a figure that will constantly rise, as the population is estimated to reach 9 billion by 2050. Additionally, developing countries such as Africa, parts of Asia and Latin America are joining the industrialization race. As a result, it has been calculated that by the year 2040, energy consumption will have risen nearly fifty percent (50%).

In order to compensate for the amount of energy needed, governments, corporate organizations, institutes and individuals have start searching for and developing new ways and technologies to generate power. Up until the past two decades, global energy supply was mostly dependent on fossil fuels. It is estimated that from 1850 until now, we have consumed more than 13 billion tons of crude oil, draining our global fossil fuels reserve into half and reaching the inevitable exhaustion in the middle of the century. This consumption has resulted in tremendous consequences regarding the environment. The pollution caused by the carbon dioxide emissions is a major one, and although the nuclear power plants that introduced later solved that problem, the lack of the presence of a permanent solution to the management of nuclear waste disposal problem meant that the focus is not only ought to be on efficient and clean ways of producing energy but also sustainable and renewable ones (Gray, 2017).

One of the main technologies that is exploited amongst others, is energy production that is generated by converting biomass into biofuel. As biofuel, we define a fuel that is produced through contemporary processes from biomass, rather than a fuel produced by the very slow geological processes involved in the formation of fossil fuels, such as oil. Biofuels can be produced from plants (i.e., energy crops), or from agricultural, commercial, domestic, and/or industrial wastes (provided the waste has a biological origin) (Wikipedia, n. d.). Biofuel production does not only provide an environmentally friendly energy source, but also uses as it’s basis, organic waste materials that are not only inexpensive and in abundance, but also do not produce any CO_2 emissions and provide an alternative solution for their management. Making use of an additional and also alternative way of producing energy does not only provide a solution to society's welfare and sustainability, but also provides a great market opportunity, as it has substantial economic value.

1.1 Energy status in Europe

Europe is another example of a continent that consumes and demands more energy that it can produce. More specific, Europe annually consumes an average of 16 million terajoules of energy with a slightly tendency to increase as the graphical illustration suggests ***(figure 1)***. From the aforesaid, Europe only produces around 42 % of its own energy, while 55 % is imported from outside of the Union and mostly out of Russia and Asia. On top of that, in 2018 Petroleum products (including crude oil) still account for a significant share of the total available energy. More specific, Petroleum products (including crude oil) account for 36 %, natural gas for 21 %, solid fossil fuels around 15 %, renewable energy for 15 % and nuclear energy 13 % ***(figure 2)***, (Eurostat, 2015).

Figure 1. Total energy consumption in Mtoe (million tons of oil equivalent)

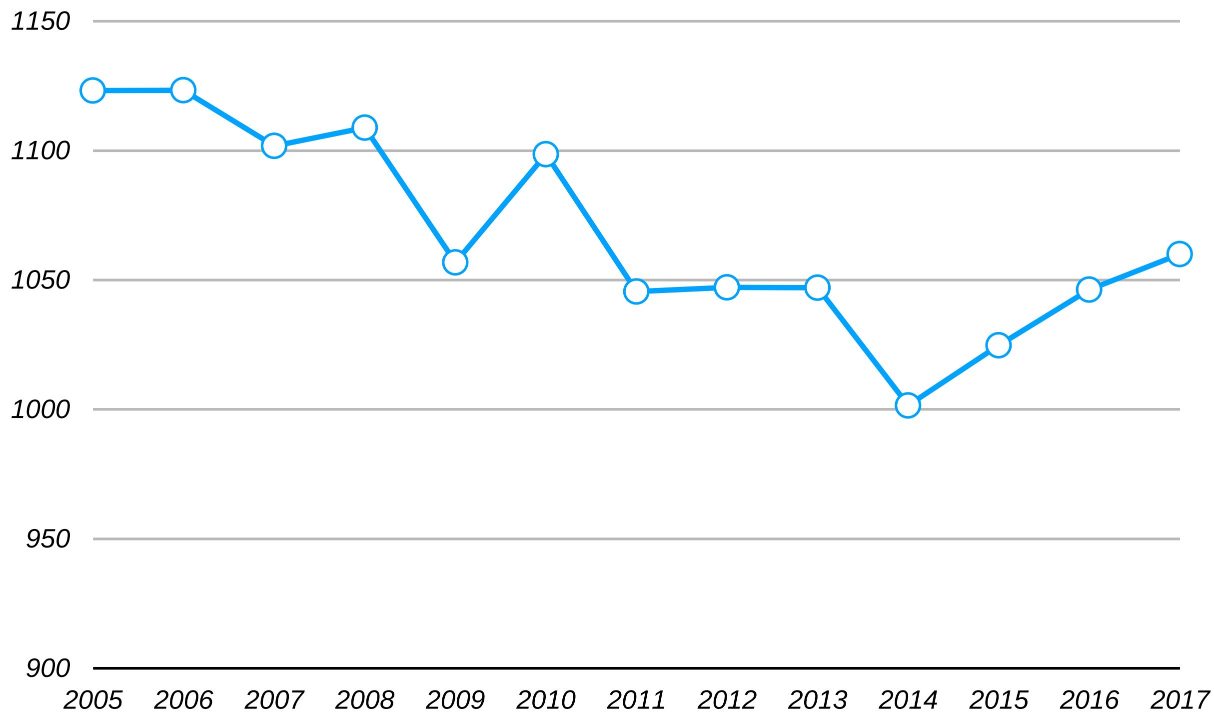
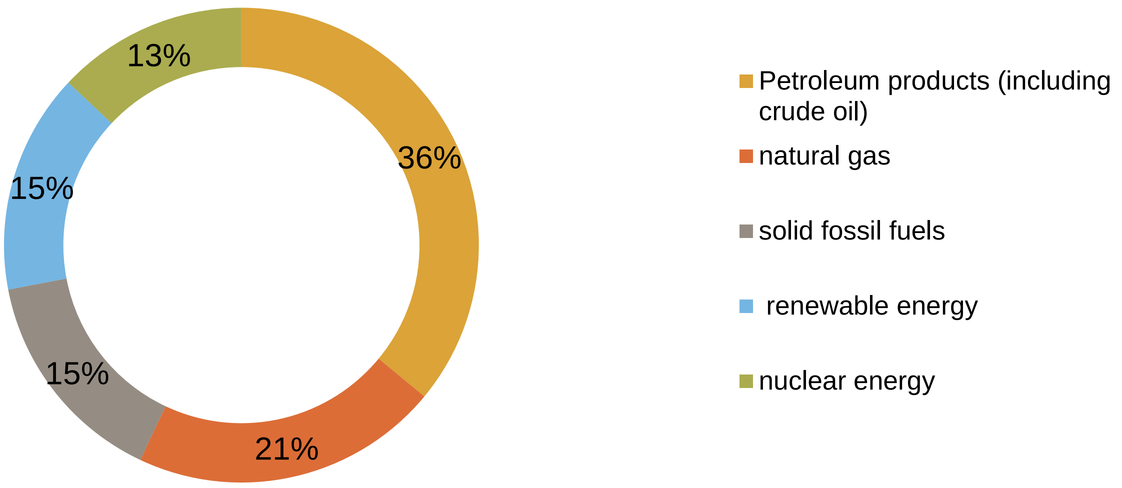


Figure 2. Energy mix in the EU (2018)



Given these facts and data gathered by Eurostat and the European Environment Agency, the European Commission has concluded that the European Union in the medium to long term period, is going to face tremendous environmental catastrophe and also become less energy sustainable, further reducing their energy independency. For this reason, EU has taken initiatives and actions in order to counter these forecasts. More explicit, the European Council that was held in October 2014, announced the 2030 climate & energy framework and targets of the European Union in regard to the environmental protection. The targets for renewables and energy efficiency are also included.

Key targets for 2030:

- At least 40% cuts in greenhouse gas emissions (from 1990 levels)

- At least 32% share for renewable energy

- At least 32.5% improvement in energy efficiency

(*The targets and framework are going to be evaluated and reformed if needed after the year 2020)*

The adopted framework intents to drive European States towards a low-carbon economy and build an energy system that ensures an affordable energy for all consumers, increases the security of the EU's energy supplies, reduces the dependence on energy imports, create new opportunities for growth and jobs and brings environmental and health benefits through reduced air pollution (Europa.eu, n. d.).

Apart from that, European commission has also created and funded various research and development programs that support innovation and research developments in all fields including the energy field. One of the largest ongoing programs is HORIZON2020. Horizon 2020 (H2020) is the largest European funding program that has ever been created with the sole purpose of helping and boosting great ideas from the lab and implement them into the market. With a lifespan of seven years (2014-2020) the program has provided more that 80 million euros, without the potential funding of private investors, to research centers and individuals and has created strong foundations for securing Europe's global competitiveness. (Europa.eu, n. d. a)

The Program was proved to be extremely effective as many companies and research centers were able to implement their innovative projects into market-ready products without the barriers and obstacles of penetrating the market, including research and innovation costs. Such example is the BIO4A H2020 Project which has demonstrated the first large industrial-scale production and use of sustainable aviation fuel in Europe, and intents to investigate the potential of recovery of dry marginal land in Southern EU. The company with the Coordination of the Italian research organization and the corporation of the Renewable Energy Consortium for Research and Demonstration of the University of Florence, was able to scale up the industrial production and the market uptake of sustainable aviation fuel, made from lipids, such as Used Cooking Oil (Benetti, 2018).

Another example is the project of BIOFIT, which was also been funded under the European Union's Horizon 2020 research and innovation program and has developed and examined technical measures that can be applied to existing production plants that support bioenergy utilization as an alternative to fossil energy. The examined bioenergy retrofits include bioethanol, biodiesel, bio-kerosene and renewable fuels and biomass-based heat & power generation, while according to research the bioenergy retrofitting can create opportunities in five industry sectors, namely first-generation biofuels, pulp and paper, fossil refineries, fossil firing power and Combined Heat and Power (CHP) plants. Also, one of its partners in this project is the Hellenic Petroleum, Greece (fossil refineries), with whom they have conducted a case study in order to investigate the Hydrotreated Vegetable Oil (HVO) production capabilities and the environmental and economic viability of the proposed retrofit in the Thessaloniki refinery of Hellenic Petroleum (Biofit, 2021).

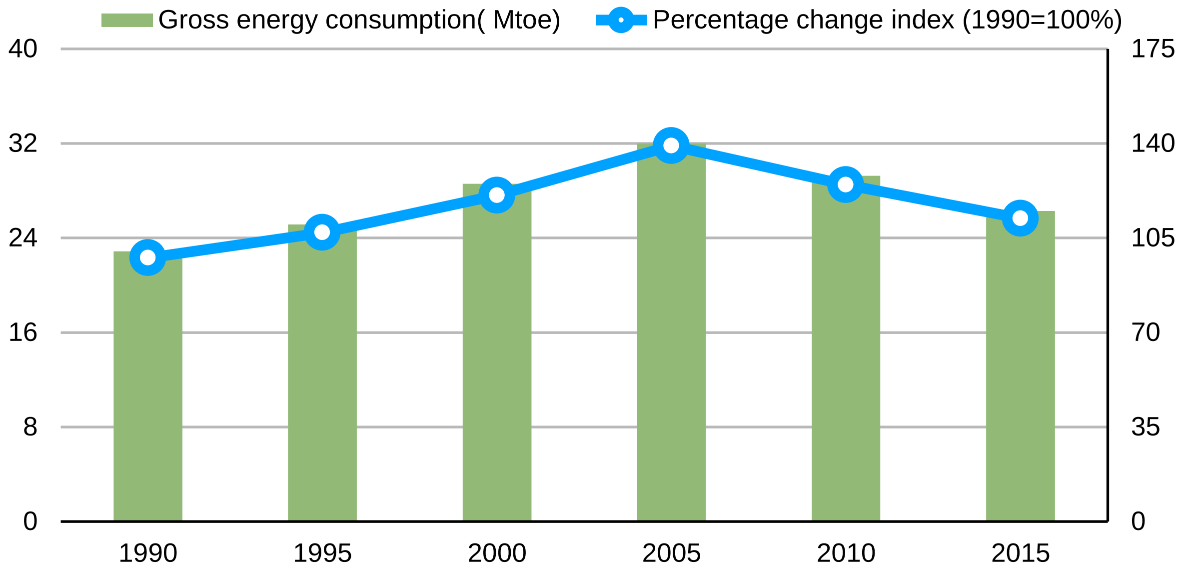
It is vital to not only highlight the significance of the H2020 program results and opportunities that it has provided, but also the general direction and framework that the European Union has chosen in regards to the upcoming energy crisis situation. The European Union has made clear that it has acknowledged the importance of the energy independence, the need to exploit alternative energy sources and most importantly that is capable and willing to take actions and invest in renewables and environmentally friendly energy sources and technological innovations.

1.2 Energy situation in Greece

1.2.1 General overview

Greece has been a European member country since 1981, located in the southern mediterranean border of the EU and is a developed country with its economy ranked 51st world's largest and 16th largest in the 27-member European Union. Its average Gross Domestic Product (GPD) is evaluated at 218 billion dollars per year and its economy is based on the tertiary sector by 80% (services), secondary sector by 16% (Manufactural and Industrial sector), with the primary sector (Agricultural sector) contributing only 4% to the national economic output. The global financial crisis in 2008 affected the country heavily which had resulted in the dramatic decline of 27.2% of the county's GPD and also the economic stagnation which was a direct consequence of the reduction of private investments and state expenditures. The deep economic regression also played a major role in the energy sector of the country, as the final gross energy consumption in the Greek energy system experienced a massive decline due to the decrease in industrial activity. More explicit, despite the increase by 42.5% during the period 1990–2008, after the peak of 31.8 Mtoe in the year 2008, the consumption started to drop and in 2015 it amounted to 24.4 Mtoe ***(figure 3)***. Despite that fact, Greece was still unable to cover the energy and electricity demand from domestic primary energy sources and was counted on imports from foreign counties in order to cover the deficit (Kaldellis, Spyropoulos, Chalvatzis & Paliatsos, 2003).

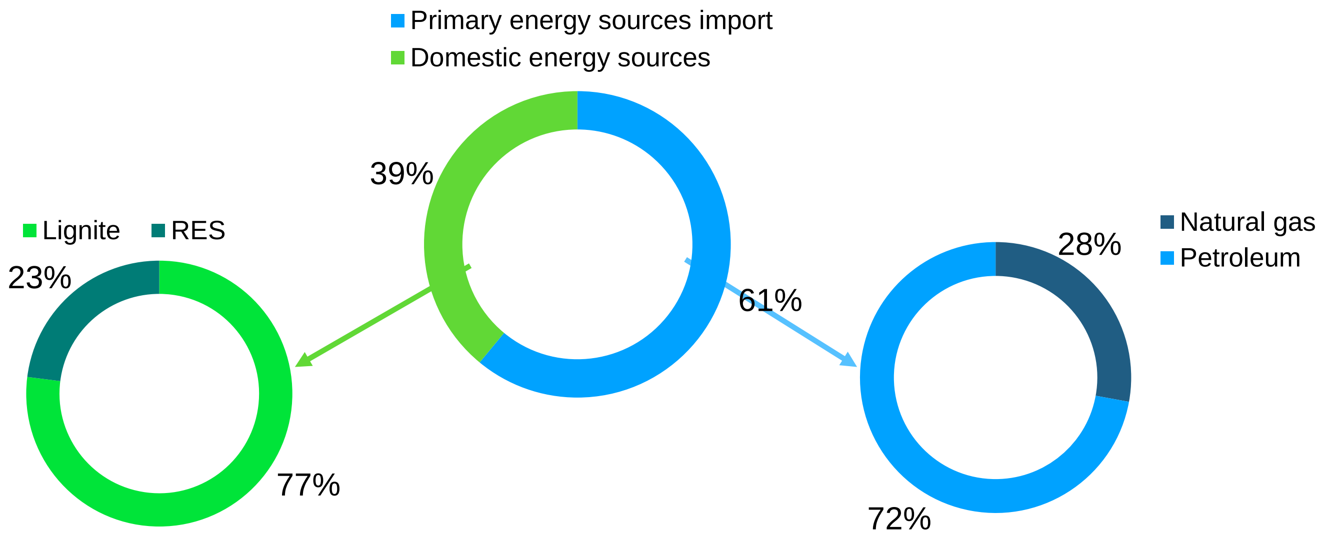
Figure 3. Final energy consumption in Greece (2015)



1.2.2 Present energy mix in Greece

Greece is one of many European countries that is mainly energy-depended from imports. According to the data gathered by the World Bank in 2015, Greece energy import net reaches 64.1 %. More specific, from the total primary energy sources, 61% is imported (mainly petroleum 44% and 17% natural gas), while the remaining 39% of the domestic energy sources are primarily lignite with 77% and only 23% are attributed for the Renewable Energy Sources (RES) ***(figure 4)***.

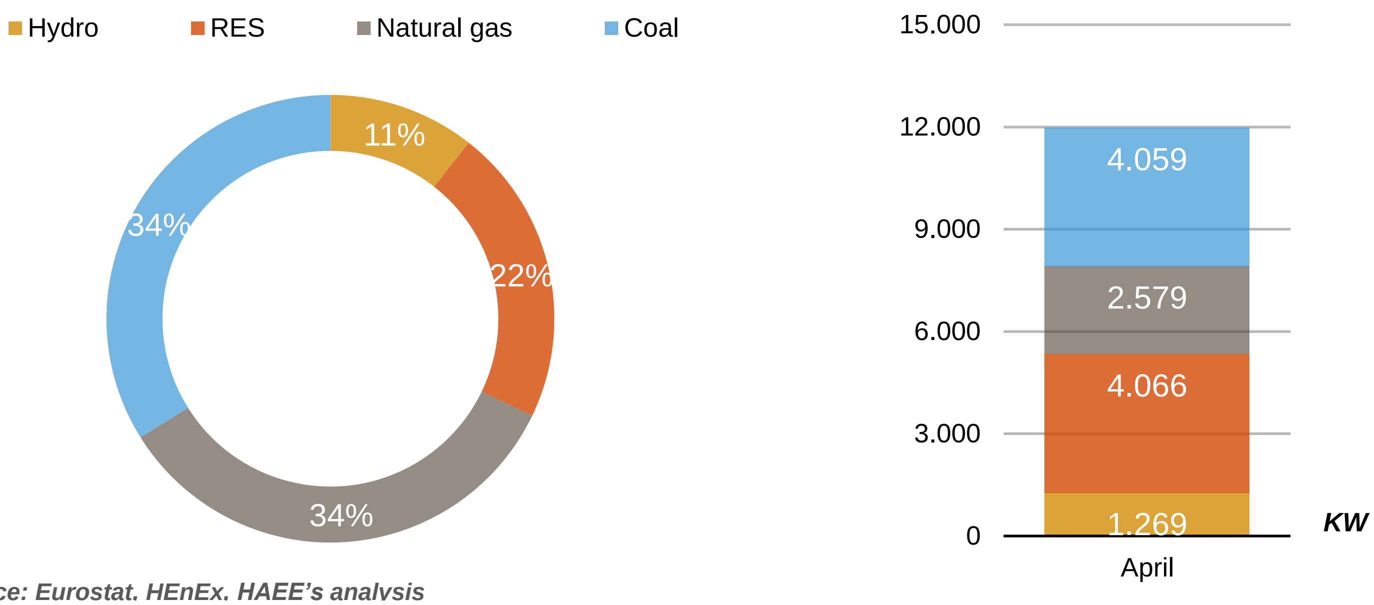
Figure 4. Primary energy balance in Greece (2015)



Furthermore, the Greek energy sector is heavily dependent on fossil fuels as 82,57% of the total energy consumption in the country is based on fossil fuels, 54% being petroleum products alone. Petroleum is used on transport, industrial sector and for electricity conversion mostly for the non-interconnected islands. Energy production in Greece is generated mainly by the state-owned Public Power Corporation (DEI) and accounts for 85,7 % of all the electric energy demand in Greece, while up until recently (2015) almost half of it (48%) was produced using lignite. Using lignite as fuel for steam-electric power generation, is not only inefficient as it has relatively low heat content but is also extremely harmful to health and responsible for the production of a substantial part of the national air pollutants (Energypedia, 2020).

Those facts in addition with the EU regulations and the economical unviability of the energy system have forced the State to initiate a reform of the electricity fuel mix in the country. Although, some laws and regulations were pushed back and delayed due to the financial crisis, Greece has made substantial progress in diversifying the electricity fuel mix. According to the latest available date, in the present Gross electricity mix, coal is now reduced to 33.9% and is accountable for generating 4.059 MW, natural gas is at 33.96% with 4.066 MW electricity generation, Hydro is the third-largest energy source in electricity generation accounted for 10,6% with 1.269 MW and RES are now attributing on 21,54 % mainly from wind and solar power with 2.579 MW of electricity generation ***(figure 5)*** (HAEE, 2019).

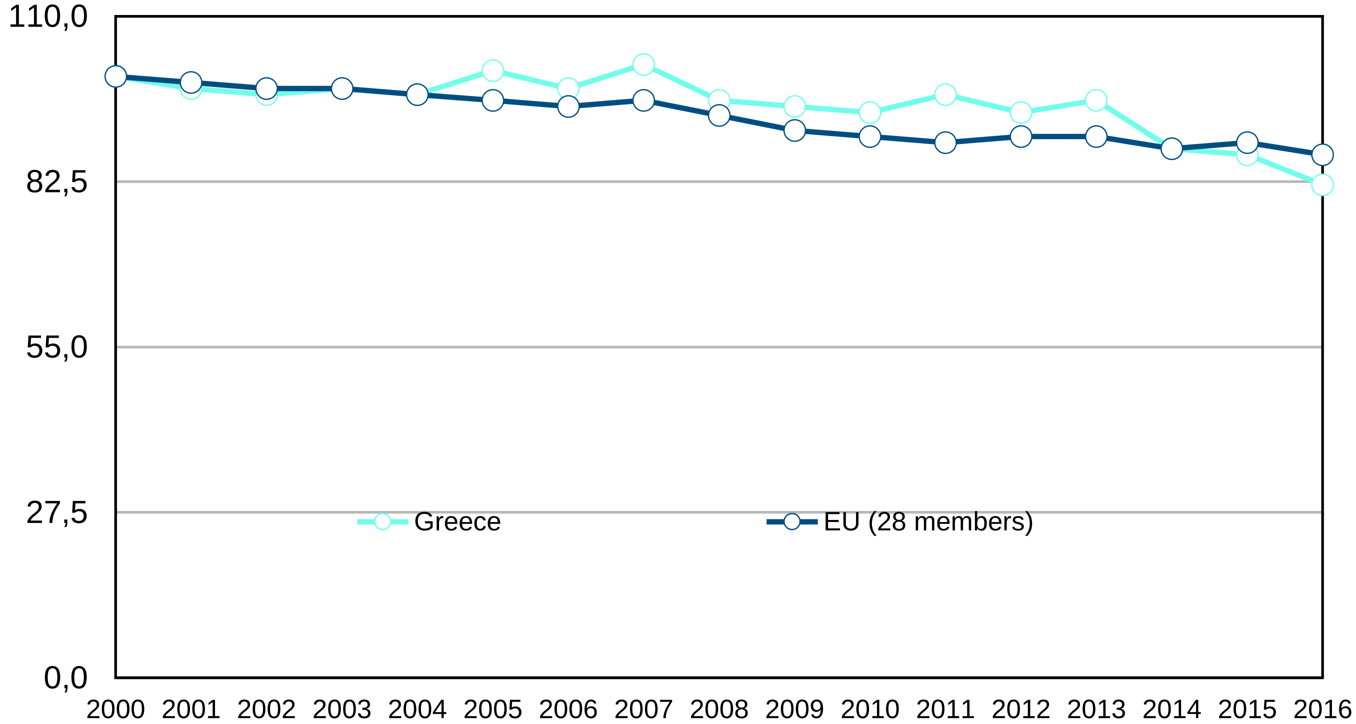
Figure 5. Gross electricity production by fuel (2019)



Source: Eurostat. HEnEx. HAEE's analysis

Greece is far from being an energy independent country and comply with all the EU regulations on clean, sustainable energy and electricity production and also on reducing greenhouse gas emissions. Although, positive steps have been made and some EU targets have been met, such as the reduction of greenhouse gas emissions by 18% from 1990's levels, they were mostly achieved due the effects of the economic regression and lack of investment in the industrial sector rather than by a long term and viable energy sector reform ***(figure 6)***. It is crucial for Greece to commit and invest on an alternative energy production system that accounts for the future framework and policies of the EU and also to capitalize on the upcoming energy market shift from traditional methods of producing energy to renewable and environmentally friendly ones. It will not only secure the future energy supply, but also accelerate the economical and technology innovational growth by exploiting its massive domestic reserves of renewable energy sources.

Figure 6. Total greenhouse emissions reduction percentage (2016)



1.2.3 RES reserves and energy potentials

Greece, despite its small geographical area in comparison with other EU member states, has relatively large amounts of domestic reserves of renewable energy sources in all fields (wind, solar, hydro, biomass). In detail, due to the fact that Greece has a vast total coastline, with very strong wings, especially in the northern and southern parts of the Aegean, it has the second-best potential in wind energy in Europe after the United Kingdom. It is estimated that the total technically exploitable wind potential in the country is 44 TW/h per year, which is around 88% of the total annually energy consumption (50.1 TWh in 2016). The total installed capacity for wind energy as by December 2016, is 2,370 MWh, out of which 62% is based in the island of Crete (Energypedia, 2020).

In the solar energy department Greece, due to its favorable annual weather patterns, is again second to Germany with an average global horizontal irradiation level of 1,500 KW/h per square meter (m^2). The solar thermal systems that already have been installed are over 4.1 million square meters which as per capita ratio is impressive, but they are mainly used as water boilers and not for electricity production as they contribute only 6% of the total annual electricity generation (Energypedia, 2020).

Greece has also promising hydro energy reserves and capabilities. The combination of the fact that is a country that is entirely surrounded by water and the various elevation differences means that there is exploitable potential for energy conversion. Right now, the total installed capacity of small-hydro powered plants (SHP) in Greece are 223 MW and only one is located on the non-interconnected islands capable of producing 300 kW of electricity. On the other hand, due to the described above vast number of total coastline and the combinations of strong wind currents, Greece has also high energy reserves from waves. It is estimated that about 1 TW of wave energy daily reaches the coast lines in the northern part of the Aegean but due to the high cost of the technology implementation it is still largely unexploited (Energypedia, 2020).

Lastly, there are only a few biomass energy projects that have been developed in Greece, mainly for the utilization of municipal wastes. The total installed capacity of biomass energy, currently stands at less than 50 MW for a total of 12 individual projects. There are no biomass projects installed on the non-interconnected islands. Annually, a total of 250 GWM of electricity is produced by biomass energy plants. Greece is already late in exploiting its rich biomass potential. it is estimated that the technically exploitable biomass could contribute approximately 20% to the total electricity needs of the country. Conclusively, there is a relative virgin market in Greece for the development of investments in electrical energy production from biomass. Therefore, a plethora of opportunities for generation of electricity generation from biomass exists, but in many cases, waste and sewage are simply discarded in the environment, along with all the negative consequences (Energypedia, 2020).

For this reason, in the next chapters of this thesis we are going to explore, develop and present an alternative olive oil waste management solution by taking advantage of the exploration of organic wastes to biofuel or biogas for electricity production. Bearing in mind the lack of biomass projects installed on the non-interconnected islands we are going to focus our research on the island of Crete due to the fact that it contains a valuable number of RES reserves in general while olive oil production is one of the main economic activities on the island. Additionally, a relatively large number of RES projects has already been implemented.

Also, in order to seize any available opportunity for investments, a detailed and feasible business plan will be developed that will examine and take into account, first of all, the production and the olive oil waste volume of the island, its biofuel production capabilities, the market demand, the potential profits and also the initial capital and investments that this project will require. It will examine the legal frame and the potential support of state or European funding and finally it will examine the cost of the facilities, equipment and technologies that will be utilized.

2 ENERGY SITUATION IN CRETE

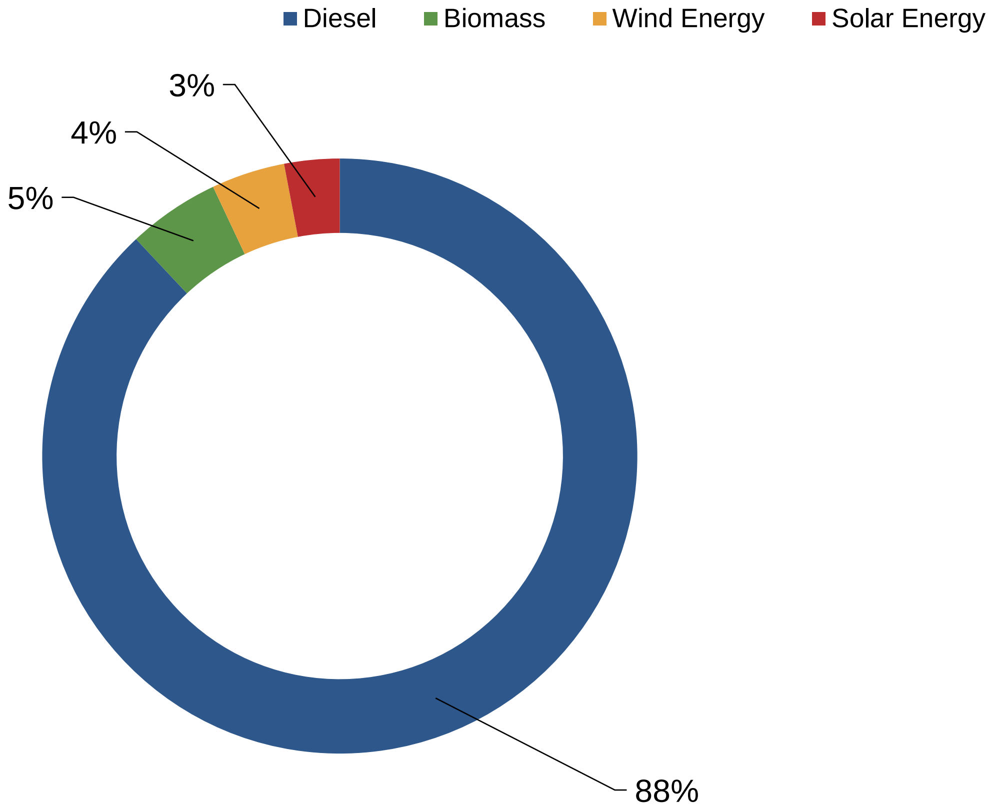
2.1 General overview

The reasons why the island of Crete was chosen as the main focus point of this master thesis research are mainly the extraordinary characteristics of the island's economy in addition to its current energy situation. More specific, Crete's economy is predominantly based on services and the tourism industry. However, the agricultural sector is strongly present and plays a significant role to the island's economy. Crete is one of the few Greek islands that can support itself and has a viable economy even without the contribution of the tourism industry. These facts can also be supported by the stability of the island's GDP which had a marginal tendency to improve despite the Greek economic regression (2008).

On the other hand, Crete is far from independent, as far as energy production is concerned. As described in the previous chapter, Crete is a non-interconnected island and as such, is depended heavily on fossil fuels and especially on diesel. Diesel is also the only fossil fuel that is used for electricity generation on the island. Its main electricity production plant is located in the island's capital city, Heraklion, and is one of the most pollutant and least energy efficient power plant in the country, despite some efforts to modernize some facilities. This is the reason why the production cost of electricity on the island is extremely high and varies from 156,5 euro/MWh to 330 euro/MWh depending on the production facility. It is noted that this cost does not burden the consumers on the island exclusively, but the cost is divided across the county (Καμάρας, Κάπρος, Παπαδόπουλος, Ασλάνογλου, Κανναβού, Νάνου, Ντελκής, Περονικολής, Πολυμενόπουλος, 2016).

What is contradictory but at the same time encouraging is the fact that Crete, despite all the external factors and the energy sector barriers which arise mainly from its geographic position and the terrain layout, has a large percentage of RES contribution in the primary energy balance of the island. More explicit, the Renewable Energy Sources contribute almost 12% and if only electricity production is taken into account, they contribute 23,7%. This percentage is extremely high and is considered the maximum that a non-interconnected island can achieve even for the European Union's energy framework and targets for 2030. That alone, reflects on the RES reserves and RES potential of the island. An illustration of the island's Primary energy balance per source is presented below ***(figure 7)*** (Καμάρας *et al,* 2016).

Figure 7. Crete's Primary Energy Balance [%]

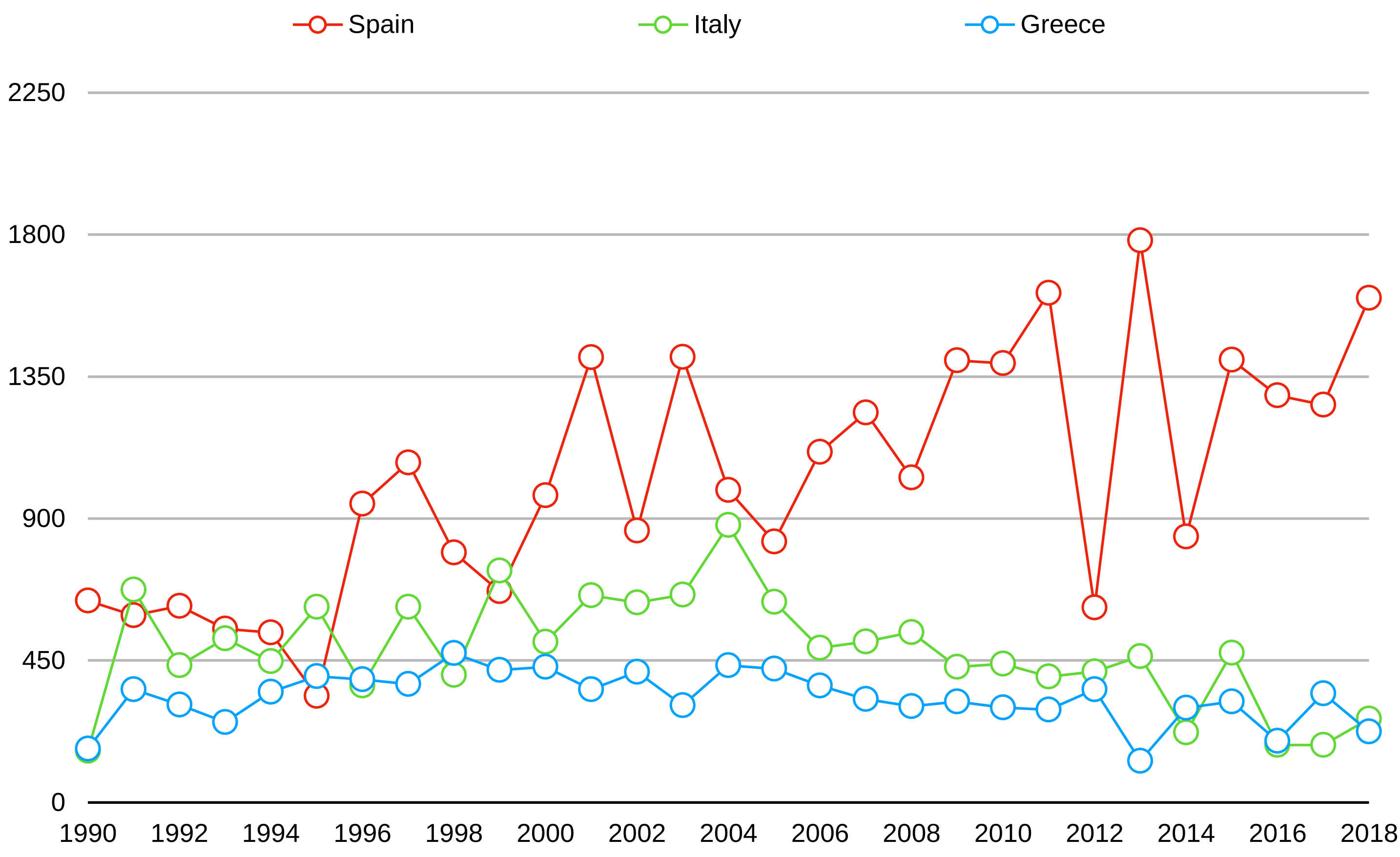


Despite the fact that the percentage of Biomass as a Primary Energy source is the largest among the RES sources, it is practically absent in the electricity production contribution, as the agricultural and forest biomass and residues are used primarily for heat generation, while a large amount of olive oil production wastes remain un-exploited. An amount which is more than capable to contribute to the electricity power deficit and demands of the island and can also provide not only a business opportunity for innovation and investment, but also a sustained organic waste management solution. For this purpose, I will further describe and assess the olive oil production of the island, the present facilities and the olive oil production wastes and disposal practices.

2.2 Present olive oil production and olive oil wastes

Despite the small percentage of GDP contribution (4%) of the primary sector (agricultural sector), one of the most important industries in Greece is the olive oil industry. Greece, belongs to the top three countries with the biggest olive oil production alongside Spain and Italy and has a relatively stable annual olive production which varies from 300 to 400 tons (1990-2018) ***(figure 8)***. Olive oil production has a significant social and financial importance to the country and is as equally important as the tourism industry, contributing to the welfare of the population for many decades, as 450.000 households earn their primary income from this sector and will continue to do so. The same is applied to the island of Crete which can be described as a scaled-down version of Greece (Olive Oil Times, 2021).

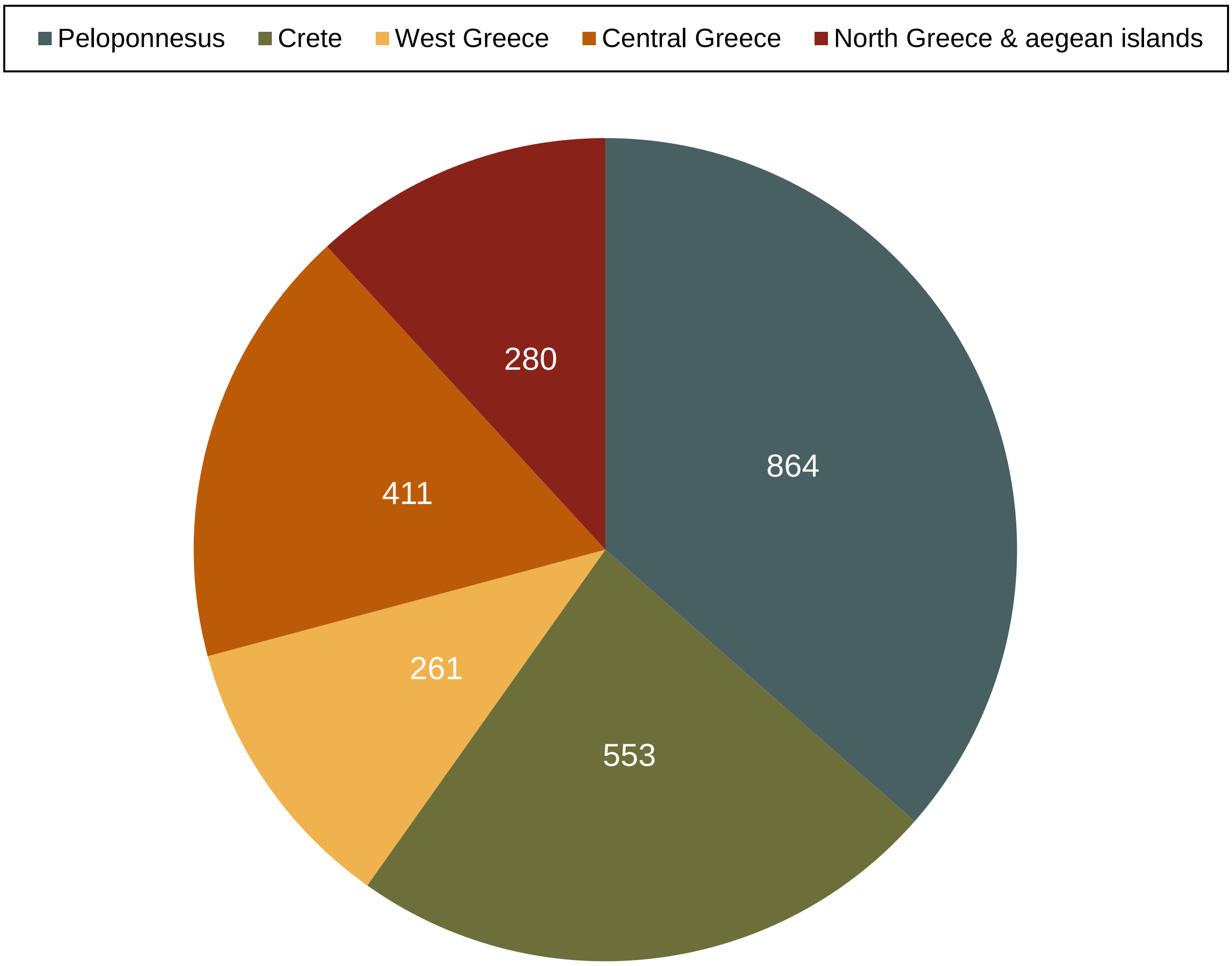
Figure 8. Annual olive oil production volume (in thousand tons) from 1990 to 2018



Source: international olive council https://www.oliveoiltimes.com/olive-oil-production-data

Crete is the second largest contributor of olive oil production in Greece and alongside with Peloponnesus, accounts for 75% of the total annual olive oil production in the country. Other regions such as West Greece, Central Greece, North Greece & Aegean islands, also have contribute significantly but to a much smaller percentage. More specific, Crete has over 30 million olive trees that occupy one-fifth to one quarter of the total surface of the island. The average olive oil production reaches one hundred thousand tons every year and in order to process this amount, Crete has over 550 olive oil mills and facilities across the island **(figure 9)** (Βιοτεχνικό Επιμελητήριο Αθηνών, 2012).

Figure 9. Geographical distribution of olive mills in Greece

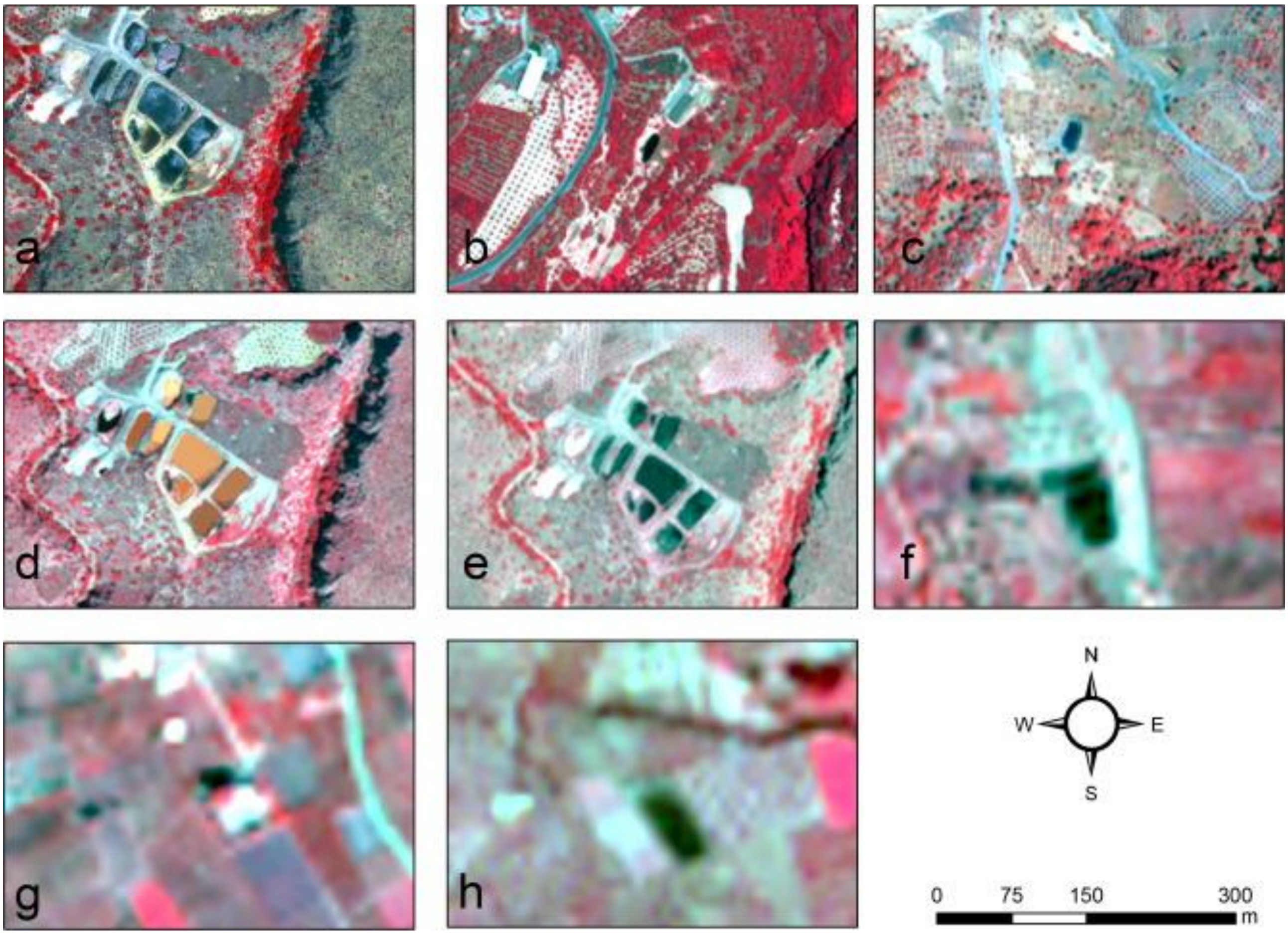


However, olive oil production also produces organic waste which, thus far, is disposed into the ecosystem and results in the tremendous pollution of the ecosystem, since a considerable amount of olive oil mill waste ends up in rivers and in the sea. For this specific reason, most of the olive oil mills in Crete are actually build near rivers or the sea in order to make the disposal “process” easier. Indeed, 90% of olive oil mills channel without any restrain, oil mill wastes into the environment, resulting in tremendous and hazardous pollution to the environment. The wastes are polluting the soil, the rivers, the sea and the subsoil.

The first result of this disposal process that can easily be observed is the aesthetic downgrade of the environment. Disposing the olive oil production wastes, leads to the production of intense fumes regarding the soil, as long as the coloration of the waters in a dark and dense hue. The biggest problem nevertheless is the fact that the olive oil wastes contain heavy organic load that causes tremendous damage to the natural environment and to the surrounding ecosystem. The composition of the wastes contains 4-16% organic compounds and 0.4-2.5 % inorganic salts. The liquid wastes can travel up to 10 kilometers from the disposal sites and pollute coasts, surface and subsurface waters. Also, the rain can carry the liquid wastes much farther, making the estimation of the actual spread extremely hard to record. From one hundred kilos of unprocessed olives, 42 kilos of vegetable oils are produced, while every cubic meter of liquid olive oil mill wastes correspond to 100 to 200 cubic meters of urban wastewater. Furthermore, the solid wastes are consisted mostly out of olive pulp and it is estimated that each year 250.000 tons are deposited in the water or soil.

An attempt to visualize the magnitude of the pollution in Crete, a research paper published in the Egyptian Journal of Remote Sensing and Space Sciences by Athos Agapiou, Nikos Papadopoulos and Apostolos Sarris is presented. This paper focuses on the island of Crete as huge quantities of wastes are produced and accomplished with the use of high-resolution multispectral satellite images and data, to identify olive oil waste disposal areas. The result showed more than 1000 Olive Oil Mill Wastes (OOMW) disposal sites that were previously unrecorded ***(figure 10)***. In the image below the waste’s disposal sites are shown as black target spots (Agapiou, Papadopoulos, Sarris, 2016).

Figure 10. OOMW disposal sites in Crete recorded using satellite images and data



These wastes could alternatively be used and exploited in order to contribute in the RES balance of the island and also to the energy independence of the olive oil mills themselves, as they need very large amount of heated water for their production process. A large-scale solution like the above mentioned has not been implemented yet, mostly due to the fact that until now the technical and financial restrains were outweighing the benefits.

3 OLIVE OIL PRODUCTION METHODS AND TECHNOLOGIES

3.1 Olive Oil fruit composition

In this chapter, firstly a description and analysis of all the ingredients of the oil seed will be presented, along with the generic method for oil olive conversion and the different types of olive oil mills production methods and their derivatives. In order to have a better understanding of the process of olive oil production, a brief description of the composition of the olive oil fruit will also take place. More specific, the main ingredients of the olive oil fruit are: (Fedeli, 1997)

i) Water

Water is one of the main ingredients of the seed and it accounts for more than 70% of its total weight. The amount of water present in the fruit is of major importance as it is responsible for the final shape of the seed and also its performance on olive production. It is noted that after years of research, specialists have concluded that the more water is present in the fruit the fewer olive oil it contains and therefore produces.

ii) Oleuropein

Oleuropein is another ingredient of the olive fruit which is responsible for the bitter taste of it. This chemical substance is actually a Polyphenol which is found in a considerable amount in unripe olive seed. In ripe olive seed this substance is either absent or in minimum amounts. Either case, this is not a problem in the olive oil production as Oleuropein isn’t soluble in olive oil and it is easily discarded amongst the vegetable liquid wastes.

iii) Sugars

Olive fruit also contains sugars such as glucose, fructose, mannose, lactose, galactose and sucrose. The latest, are observed in very minor quantities and are practically absent if the seed reaches maturity.

iv) Proteins

The olive fruit contains a variety of proteins in a percentage range of 1.5 to 3%. This percentage actually depends on the maturity phase of the fruit and variety of the olive seed.

v) Olive oil

The most valuable ingredient of the olive seed is the olive oil itself. It is contained in a percentage range of 17-35 % of the total weigh of the fruit. The percentage depends as seen above on the water of the seed, its maturity and variety of the olive fruit.

vi) Other ingredients

A variety of other ingredients can be found in the composition of the olive fruit such as inorganic elements (iron, calcium, potassium), as well as a variety of acids in a percentage range from 0.1 to 0.17.

3.2 Olive Oil extraction process

3.2.1 Olive collection

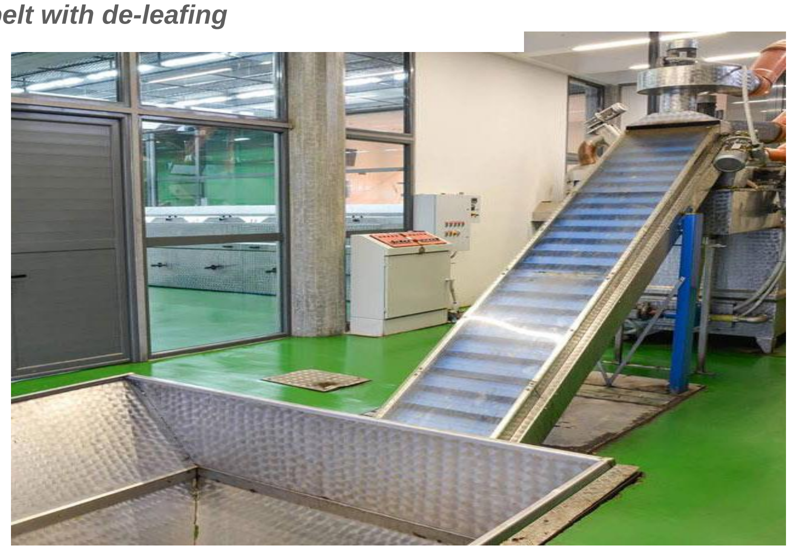
The olive oil extraction process has as a starting point the harvest of the fruit. The harvesting takes place for about 4 months per year (early November until late February) and is a very important factor, as the time of the collection (ripe olive fruit or unripe), the collection method (the damage of the fruit from the collection process) and the period between collection and oil extraction, all play a significant role in the total olive oil production volume, the acidity of the final product, as well as its taste (Vossen, 2007).

3.2.2 Olive fruit receival and de-leafing phase

After the olive harvest, the first stage in the factory process flow is placing the olive in a collection vat ***(figure 11)***, which drives them to enter the mill on a convey belt, while powerful air suction from above de-leaves the olives and removes any foreign object and small branches ***(figure12)***. This process removes 90% of the leaves while the other 10% is ground into paste with the olives and pits. The fewer foreign objects enter the process of milling, the better characteristics the final product will have (taste, acidity, volume extracted) (Vossen, 2007).

Figure 12. Collection vat

Figure 11. Convey belt with de-leafing



3.2.3 Washing phase

Following the de-leafing process, the olive fruit is channeled through a washing head-unit where the final removal of any remaining foreign objects is taking place alongside with the removal of any dirt, dust and other liquid substances ***(figure 13)***. Actually, the washing phase isn't always necessary and is advised not to be performed unless the fruit made contact with fertilizers or the ground during harvest. This is because water adds humidity in the fruit and oil/water emulsions are created. A fact that contributes in the loss of the extracted olive oil (Vossen, 2007).

Figure 13. Washing phase

3.2.4 Olive crushing - olive mill

In the next phase, the olive fruit is crushed to its cores in order to extract the olive oil. There are two main types of machinery that are used for this purpose: Stone mills and Hammer mills. The Stone mills system is the most common and most used method since ancient times. They consist of one large stone base with two or three vertical placed large stone mills inside a metallic bowl, with sometimes small triangle shaped extensions attached to the bottom, in order to spread and recollect the olive paste. The slow rotational movement of the stone mills doesn't allow the temperature of the olive paste to rise high and that results in keeping the emulsion form to the minimum. On the other hand, they require large facilities as they are quite large in size. The slow movement of the system means that the oil extraction process is more time consuming, which raises the operating costs significantly. This is why the stone mill system is used less and less nowadays and the oil producers opt for the more advanced Hammer mills systems ***(figure 14)***, (Vossen, 2007), Giovacchino, Sestili, Vincenzo, 2002).

The Hammer mill system uses a high velocity rotating metal axis which bashes the olive fruit against a metallic surface. The advantage of this system in comparison with the more traditional stone mill system, is that it's a much faster production method and as the system is more compact, it requires smaller, in size, facilities which translates in low operating costs. However, the disadvantage is that, due to the high rotation speed, the olive paste reaches higher temperatures, which results in a large formation of oil/water emulsion ***(figure 15)***.

Figure 14. Stone mill system

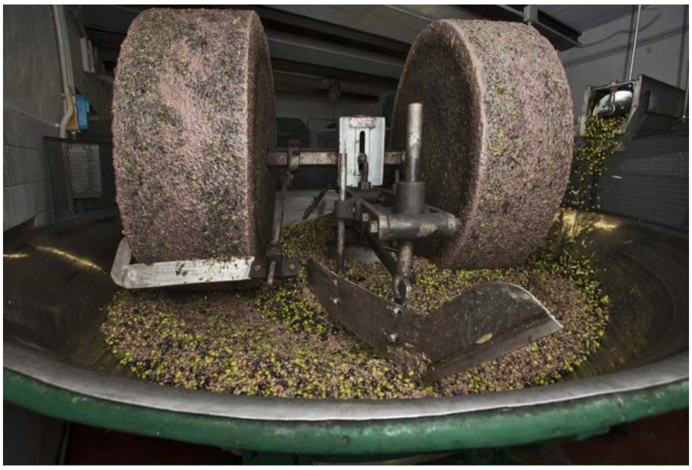


Figure 28, Hammer mill system

3.2.5 Mixing phase (malaxing)

In the mixing phase, the olive paste is prepared for the olive extraction. A malaxer head unit is used to unify the crushed olive paste with the reduction of the formed oil/water emulsion being the end result. This procedure is only necessary if the paste is produced by a hammer mill, but is often used by regular stone mill facilities too. The reason why is that this process removes the concentration of oxygen in the mix which results in better quality and taste of the final olive oil product ***(figure 16)***, (Vossen, 2007), (Κυριτσάκης, 1989).

Figure 39. Vertical arranged malaxer

3.3 Olive oil extraction methods and technologies

Up to this point, the flowchart and the phases of olive oil extraction are more or less the same in all olive mill factories. For the important phase of the oil extraction however, different methods exist which are defined by the type of the oil mill. There are 2 main methods that are used; Hydraulic Presses which are used by traditional oil mills and centrifugal decanters which are used by two phase or three phase oil mills.

3.3.1 Traditional oil mill complex

Pressers as a form of extracting the olive oil have been used for many years by traditional oil mill complexes. After the mixing phase, the olive paste is spread into circular metallic disks which are then, stacked on top of each other up to ten at a time and then placed on the presser. A Hydronic piston applies pressure, which fluctuates from 300 to 500 kg / m^2. Thus, the solid olive paste is separated from the liquid oil and the wastewater (vegetable liquid). The olive oil is finally separated from the wastewater using a dedicated separator which utilizes the difference in specific gravity of the 2 substances (water 1.00 and olive oil 0.915) and finally the olive is stored in stainless steel tanks. This method apart from the high-quality olive oil produced also has the same major advantages on the Olive Mill Wastes' (OMW) output ***(Figure 17)***.

Firstly, the production process in the traditional mills, uses minimum water and thus the washing of polyphenols is minimized, water is used mainly for the washing phase and not for the oil extraction phase. The end result is less liquid OMW and also less moisture in the pomace residue, making it much easier to handle. The pomace produced in traditional mills is suitable for burning and with further process can be used for heat production. Despite these facts, the traditional mills do not optimize the production process as it's a non-continuous process, with quite large waiting periods and longer production time from harvest to oil extracting making it a less cost-effective procedure. Also, despite the fact that its solid wastes are low in water and therefore much easier to handle, the Oil Mill Wastewaters (OMWW) produced are extremely harmful to the environment. More specific, the liquid produced from the extraction process contain high values of organic load and high values in COD and BOD. COD or Chemical Oxygen Demand is the total measurement of organic and inorganic chemicals in the wastewater while BOD or Biochemical Oxygen Demand is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic substances present in wastewater in a given period of time. In other words, BOD measures the amount of oxygen needed by bacteria to degrade organic components in water/wastewater. Both these values are measured in milligrams of oxygen needed per liter of water (mg/l). More information about the composition of Liquid OMW produced by a traditional mill complex is given by the following table ***(table1)**,* (Gholamzadeh, Peyravi, Jahanshahi, 2016).

Figure 47. Traditional mill complexes flow chart

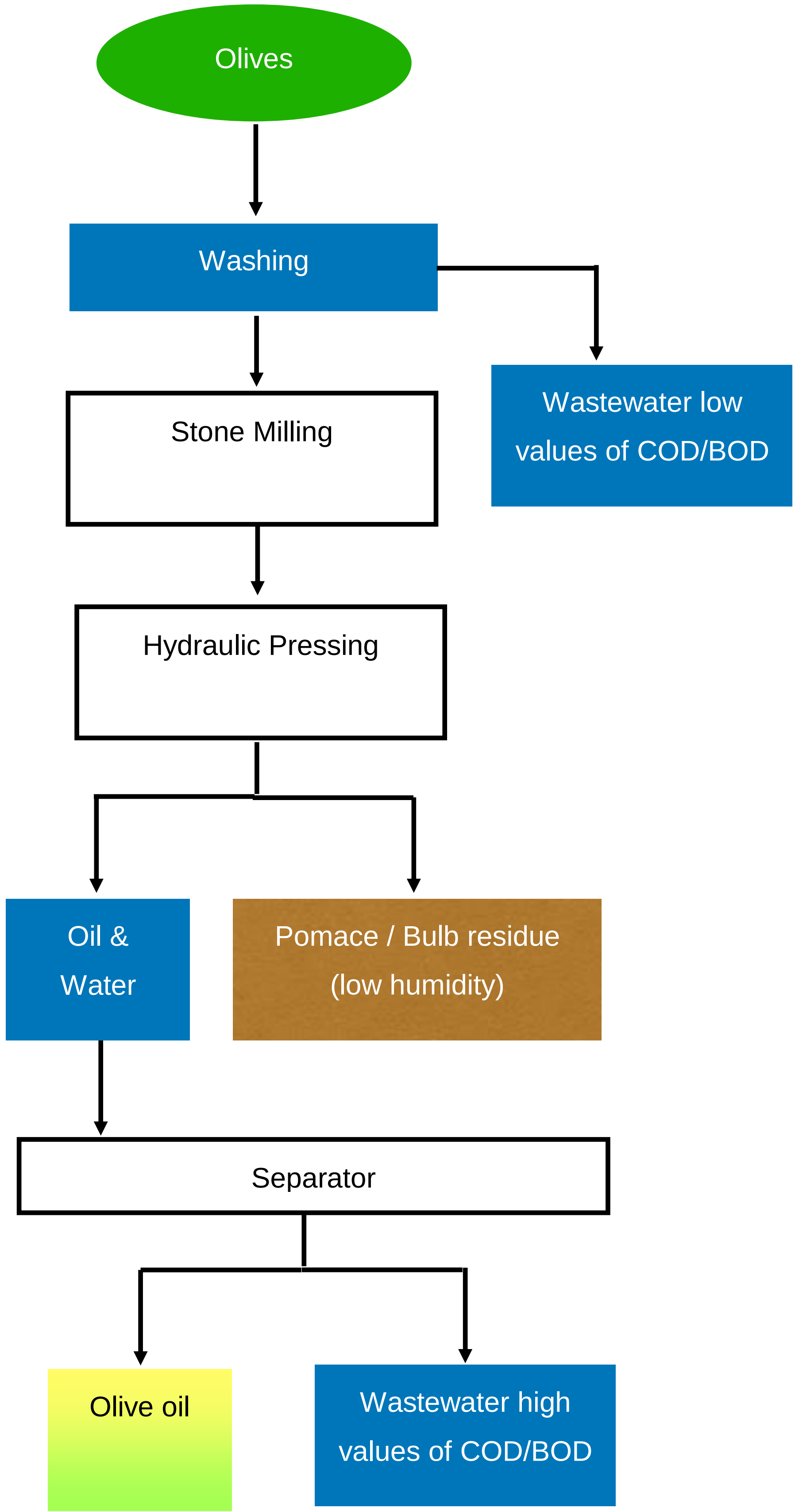


Table 1. Composition of liquid OMW found in Traditional mill complexes

WASTEWATER		
PARAMETER	VALUE	MEASURMENT
BOD	90.000-100.000	mg/l
COD	120.000-130.000	mg/l
Suspended solids	12%	net weigh percentage
PH	4,7	N/A
LIQUIDS IN POMACE		
Olive oil	6%	net weigh percentage
Humidity	25%	net weigh percentage

3.3.2 Three phase oil mill complex

Centrifugal decanters were developed in order to achieve higher rate of oil extraction from the same input of olive fruit and also, to significantly reduce the oil production time and thus the operating cost. In the three phase centrifugal decanters, water is added as a mean of transferring the oil paste into the centrifugal decanter chamber. More specific, 60 to 70 liters of water is added per 100 Kg of olive paste. Inside the horizontal decanter, a rapid spin axis applies centrifugal forces to projectile the heavy solid objects in the outer layer of the chamber, while the lighter liquids (oil/water) are concentrated in the middle. After the solid wastes have been disposed, the oil/water mixture, goes through a vertical centrifugal separator where olive oil is poured from one side and wastewater from the other ***(Figure 18)***, (Gholamzadeh, Peyravi, Jahanshahi, 2016).

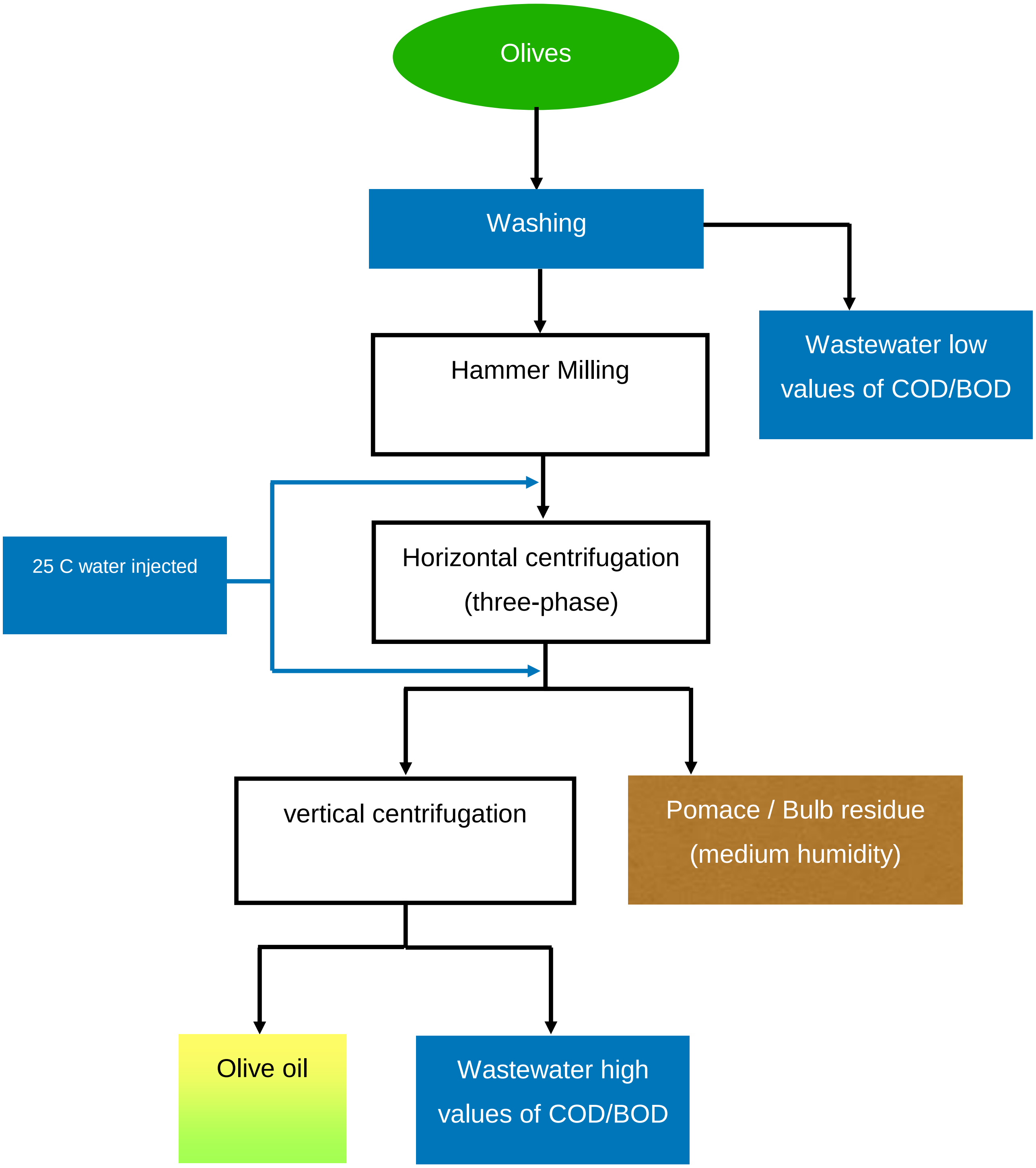
Although, the three-phase decanter achieves higher olive oil production speed and lower overall cost, it actually magnifies the OMW problem. More specific, due to the fact that it uses substantial amounts of water in the process, the final OMWW produced are almost three times as much in comparison to the traditional type oil mill but the indication of COD/BOD values are lower.

The biggest disadvantage though, is the solid OMW which due to the high concentration of humidity is not suitable to be used as a fuel for producing heat. The handling of this type of pomace poses the greater challenge in the three phase oil mill complexes. The pomace produced by this type, contains 50% humidity which is double compared with the traditional type. More information about the composition of Liquid OMW produced by three phase centrifugal oil mill complexes is given in the following table ***(table 2)***, (Τζουτζομήτρος, 2002).

Table 2. Composition of liquid OMW found in three phase mill complexes

WASTEWATER		
PARAMETER	VALUE	MEASURMENT
BOD	35.000-48.000	mg/l
COD	45.000-60.000	mg/l
Suspended solids	5%	net weigh percentage
PH	5.1	N/A
LIQUIDS IN POMACE		
Olive oil	4%	net weigh percentage
Humidity	50%	net weigh percentage

Figure 58. Three phase mill complexes flow chart



3.3.3 Two phase oil mill complex

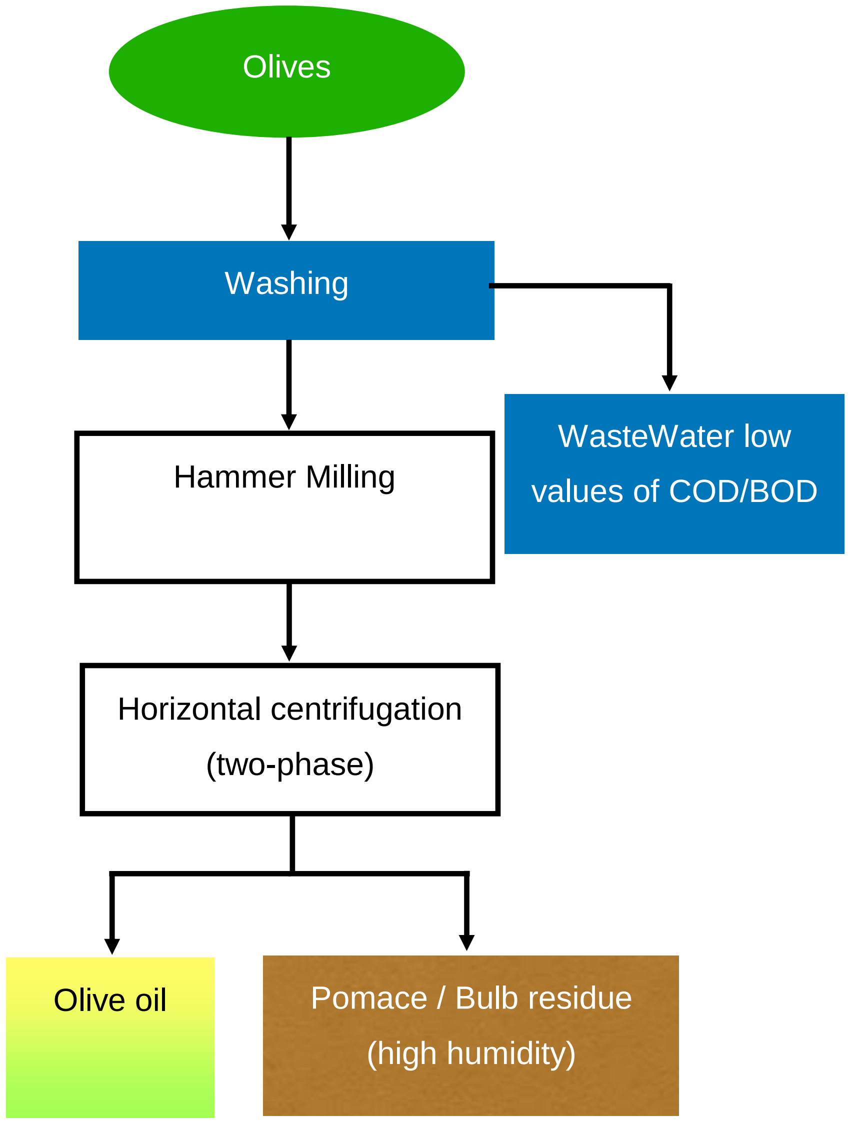
The two-phase centrifugal decanter system was developed in 1970, as a solution to the need of a less costly production method, less water consumption and easier OMW management. The two-phase method, reduces the use of water by 80%, the consumption of energy by 20% and has 25% less cost of capital. In reality, the two phase and the three-phase are quite similar. The only difference is that no water is added in the malaxing stage unless the olive fruit mix is significantly matured and the decanter separates the oil from all the wastes directly. The liquid and solid wastes are discarded from the process together. As a result, the pomace absorbs the wastewater and only minimum amounts of OMMW are produced ***(Figure19)***, (Gholamzadeh, Peyravi, Jahanshahi, 2016).

This solution despite the fact that the OMWW is significantly reduced, a bigger problem is created for the oil mill solid wastes (OMSW) as the end-product, contains up to 70% humidity and twice as much concentration of polyphenols and higher values of BOD. This type of semi-liquid wastes cannot be used to produce organic fertilizers or be turned into heating fuel. More information about the composition of semi-Liquid OMW produced by two-phase centrifugal oil mill complexes is given in the following table **(table 3)**, (Τζουτζομήτρος, 2002).

Table 3. Composition of liquid OMW found in two phase mill complexes

WASTEWATER		
PARAMETER	VALUE	MEASURMENT
BOD	1.400	mg/l
COD	5.000-6.000	mg/l
Suspended solids	-	net weigh percentage
PH	5.5	N/A
LIQUIDS IN POMACE		
Olive oil	3%	net weigh percentage
Humidity	60-70%	net weigh percentage

Figure 66. Two phase mill complexes flow chart



In reality, with this type of process, the oil mills shifted the problem of waste management to pomace process facilities and did not manage to provide an holistic solution. The pomace is much heavier and thus more difficult to transport. It is also more humid which means more time and energy consumption in the drying process. Moreover, after the processing, the wastes still contain heavy loads of environmental hazardous substances.

3.4 Collective analysis of OMW from all three Oil Mill Types

In order to provide a better visualization of the direct comparison between all three olive production methods, the input and output data of each method will be presented and also the characteristics and volume of their waste in a scenario of 1000 kg olive fruit input in all three types ***(table 4)*, *(table 5)*,** (Nuri, Abdurrahman, Ayse, Fusun & Adem, 2004).

Table 4. Comparison of input and output data for all three milling methods (processing 1 ton of oil fruit)

PRODUCTION METHOD	INPUT	INPUT VOLUME	OUTPUT	OUTPUT VOLUME (KG)
TRADITIONAL MILL COMPLEX	olive fruit	1 ton	olive oil	200
	washing water	100 lt	solid wastes/pomace (25% humidity and 6% olive oil)	400
	energy	45-65 kWh	wastewater	600
THREE PHASE MILL COMPLEX	olive fruit	1 ton	olive oil	200
	washing water	100 lt	solid wastes/pomace (50% humidity and 4% olive oil)	500-600
	decanter water injection	500-1000 lt	wastewater	1000-1200
	energy	90-110 kWh		

TWO PHASE MILL COMPLEX	olive fruit	1 ton	olive oil	200
	washing water	0-100 lt	semi-solid wastes/pomace (70% humidity and 3% olive oil)	800-1000
	energy	70-90 kWh		

Table 5. Comparison of OMW composition between oil mill types

COMPOSITION	TRADITIONAL PRESSING MILLS	THREE PHASE MILLS	TWO PHASE MILL
OIL MILL SOLID WASTE	330	500	800
OIL MILL WATER WASTE	600	1200	250
VEGETABLE WATER OF OMWW	94	90	99
BOD (mg/l) OF OMWW	100.000	80.000	10.000
POLYPHENOLS (mg/l) OF OMWW	203	164	200

Clearly, the two-phase oil mill process is producing the least amount of OMW footprint and has the smallest BOD values. Also, it uses less energy and is less water depended. Despite this fact, the method cannot be characterized as an "environmentally friendly" method, as it magnifies the problem of the OMSW management and handling. Not only that, it also requires a significant investment to convert from three phase to this type and small to medium oil mills cannot cope with that cost of conversion. On top of that, In Greece, 70 percent of all oil mills operating are three phase type and in Crete the 85%, while the two-phase oil mill owners preserve a high resistance for the conversion technology. For this reason, a more realistic OMW management solution and approach is necessary to be implemented, while at the same time will make sense financially.

4 OMWW MANAGEMENT METHODS AND TECHNOLOGIES

Given the fact that 80% of all olive oil mills on the island of Crete are three-phase mills, focus will be placed on the OMWW management and treatment proposal, as the major part of the problem occurs due to massive volume of the wastewaters they produce. Understanding the necessity for wastewater management and handling solutions, numerous methods and technologies have been developed over the years. These methods fall under three main categories: **physical, physiochemical** and **biological treatment**.

4.1. Physical treatment methods

The physical methods for OMWW treatment have been used for many decades. The most used physical treatment methods are the Dilution, the Flotation, the Sedimentation, the Centrifugation and the Filtration. While all have shown some positive results, none of the above can by themselves reduce the organic load and the toxicity of the OMWW significantly. They are used mainly as a first step for the separation of the wastewaters that are produced during different olive oil production phases, in order to be further processed or achieve a less environmental hazardous disposal and reduce their footprint.

i) Dilution

This method is one of the simplest and most inexpensive for OMWW treatment. The dilution is achieved mostly by using water from nearside active rivers or the agricultural irrigation system and if the procedure is precise enough, it can definitely improve the fertility of the soil that is later disposed, mainly due to the potassium and sodium which are present in the wastes. The most efficient dilution ratio is considered to be 1:4 (25% OMWW and 75% water) by which the maximum organic load reduction is achieved. This method is applied by small size oil mills which produce small amounts of water wastes and thus do not require a lot of water. For the larger oil mills, which produce substantial more OWMM, this method cannot be applied due to the large amount of water that is needed for the dilution. Proposals have been made for using municipal wastes as a mean for dilution, but the enormous dilution rate needed for a safe disposal (1:100), has not made it preferable (Munir, Rusan, Malkawi, 2016), (Paraskeva & Diamantopoulos, 2006), (Niaounakis & Halvadakis, 2004)

ii) Flotation

Flotation is a method that was first introduced in the mining industry as a solution to separate different types of solid masses. The same principal was implemented as a method to separate the solid wastes that are present in the wastewaters from the oil mills. More specific, the wastewater is concentrated in a special large tank and kept in normal atmospheric pressure (1 atm). Then, pressurized air is inserted in the tank which creates thin bubbles which are attached to the solid objects reducing their density to the point that is less than the water density, so they float on top making their removal much easier. Then the wastewater is ejected from a depressurizing valve in the bottom. In many cases, different chemical substances are added such as foaming chemicals or collectors, in order to assist and speed up the separation process. Although this method has shown reduction of the PH and COD up to 30%, this method is again mainly used as a first step for further processing. The reason is that the rate of air injected to the wastewater volume is impossible to calculate, due to the fact that the solid object mass contained, cannot be accurately calculated in advance, thus making it very difficult to achieve high efficiency (Rubio, Souza & Smith, 2002), (Mitrakas *et al,* 1996)

iii) Sedimentation

The Sedimentation method is also a form of preparation for further wastewater processing and it uses the same principals as the Flotation method in exactly the opposite form. More specific, the wastewaters are concentrated in a large tank and kept for days. Once the wastewaters are completely calm, the heavier solid objects, due to their density, succumb to gravity and fall in the bottom of the tank. The wastewater is then released from the tank, leaving on the bottom any solid objects in a form of dense mud. This method reduces the volume of the OMWW by 25% but does not result in a reduction of the organic and chemical load of the wastes, as it just shifts them from the wastewaters, to the muddy substance, which is much more difficult to be treated and disposed. Also, it is a very costly, since expensive facilities are required, and time-consuming process. On top of that, in the areas that these facilities are installed, high air pollution and air stench is observed, due to the wastewaters standing still for days and often leads to the use of chemicals to reduce the scent which actually results in greater chemical load of the wastes (Georgacakis & Dalis, 1993), (Khoufi, Feki & Sayadi, 2007), (Niaounakis & Halvadakis, 2004)

iv) Centrifugation

In the previous chapter Centrifugation as an oil production method was described. In general Centrifugation produces 3 separation phases; the surface layer which is the separated olive oil, the liquid layer which is the wastewater and the bottom layer which is the heavy solid objects. This principal can also be applied for treatment of the OMWW. By using Centrifugation for wastewater treatment, the remaining solid objects can be fully separated from the liquids. Additionally, the ability is given to regain lost olive oil volume. The recovery of the olive oil fluctuates from 30 to 50 %, depending on the production method used and thus the composition of the water wastes. The reduction of the COD volumes reaches 70% but it depends on the duration and rotation speed of the decanter. In general, the Centrifugation method cannot be characterized as a solution as it is the method which creates the majority of the waste management problems. It can actually be very helpful in creating type of wastes that can be more easily treated, especially if it is used as a first step for the filtration and membrane method (Niaounakis & Halvadakis, 2004), (Sedej, Milczarek, Wang, Sheng, Bustillos & Tekeoka, 2014).

v) Filtration

Filtration is the simplest and most used separation method of mixtures that contain solid objects. It doesn't require any conditions or any specific atmospheric pressure, while it performs and produces similar separation results as the Sedimentation method and greater COD reduction levels than the Centrifugation method. It also has a very low cost of capital, but is often not preferred by the olive oil mills due to the great drawback of constant filter blockages that are occurring due to the forming of sediments. This constant and inevitable filter blocking, reduces the efficiency of the method while it raises the operational costs of the mill (Mitrakas et al, 1996).

4.2 Biological treatment methods

Biological processes for treating Oil Mill Wastewaters have been applied worldwide with impressive results. They are considered to be very reliable methods, environmentally friendly and very cost effective. The biological treatment uses micro-organisms to decompose chemical compounds which are present in the OMWW, to remove organic matter and inorganic nutrients and also to reduce BOD and COD values and to produce less environmental hazardous waste disposals. The main process methods are characterized into two main categories: **Aerobic** and **Anaerobic** treatment (Niaounakis & Halvadakis, 2004).

i) Aerobic treatment

The Aerobic treatment, is a basic waste processing method which is used to decontaminate all sorts of wastes like municipal waste, organic production wastes etc. During the aerobic treatment or aerobic digestion method, natural occurring aerobic micro-organisms, such as bacteria, protozoa and microbes, act as decomposers that are responsible for the oxidation of complex organic compound and ultimately reduce it in simple forms of carbon, which then can be safely returned to the environment (Doble & Kumar, 2005), (Niaounakis & Halvadakis, 2004).

The process takes place into a bioreactor, which simply accelerates and provides the micro-organisms with favorable conditions for growth by "feeding" soluble oxygen, organic and nitrogenous compounds. During the process and when the microbes have reached peak decomposing rate, the feeding is reduced in order to stop the multiplication and allow the biomass to stabilize, making it suitable for disposal. This process is suitable for OMWW as it reduces COD values and decomposes phenolic compounds successfully. The effectiveness of aerobic digestion depends on the volume of available soluble oxygen and nitrogenous compound fed, the PH and temperature of the wastes. Although some microorganisms can produce biogas as a byproduct of this process and more specific methane, documentation supports that not enough and constant volumes are produced in order to achieve any sustainable financial gains (Morillo, Antizar-Ladislao, Moteoliva-Sanchez, Ramos - Cormenzana & Rusell, 2009).

ii) Anaerobic digestion

Anaerobic digestion is probably the most known process of biological treatment methods and all the OMWW management methods in general. It is performed in the absence of molecular oxygen by anaerobic micro-organisms and bacteria, which have lower growth and multiplication rates that the aerobic micro-organisms. The three main steps of the Anaerobic digestion are hydrolysis, acidogenesis and methanogenesis. The latter is considered the most important stage of the process as it's the stage where biogas is produced (mainly methane), which has great economic value and importance, since it can be used to generate heat and electricity with the use of a Combined Heat and Power (CHP) plant. All modern methods that utilize the anaerobic micro-organism for the biological treatment of OMWW and simultaneously produce bio-methane, are based on the retention of large quantities of bacterial sludge. This can be achieved with the following three methods: (Rajeshwari *et al,* 2000)

1. Formation of degradable agglomerates in activated sludge combined with gas separation and sludge settling. Such systems are created in **UASB** (Up flow Anaerobic Sludge Blanket) reactors.

2. Bacteria attached to carriers with high density particles, such as **FBR** (Fluidized Bed Reactors) and **EBBR** (Expanded Bed Biofilm Reactors).

3. Incorporation of sludge agglomerates in filters into a reactor, called Anaerobic Upstream or Downstream filters.

Despite the method used, anaerobic treatment has shown effective COD and BOD volumes reductions up to 85% and in some laboratory experiments up to 95%. Bio-methane production was found to correlate with the COD removal in a ratio of 0.30 – 0.35 m3 CH4 kg−1 COD using an UASB (Up flow Anaerobic Sludge Blanket) reactor.

4.3 Physiochemical treatment methods

Physiochemical methods for the treatment of OMMW are used, when the simple physical methods are inadequate in removing the total polluting load of the OMWW. They are used combined with the physical methods in order to improve the effectiveness of the applied treatment methods. The simplest is Incineration and Flocculation, which are used as a pretreatment method while the Oxidation and Absorption are used to achieve more specific results. In general, physiochemical methods are more often used to reduce and neutralize toxic substances found in OMWW in order to transform them into a more appropriate mixture for the micro-organism used in biological treatment methods.

i) Neutralization

This is one of the most common practices used in the management of wastes characterized by heavy corrosion levels. Neutralization is used as a preprocess method before physical or biological treatment is applied. Mostly, these methods' efficiency and effectiveness depend on the PH value of the waste mixture. In other words, Incineration is simply the process which neutralizes the value of the waste mixture's PH by adding acid or base depended on OMWW initial PH measurement in order to reach the PH requirements of each method. In most cases the OMWW have an acid PH, ranges from 3 to 6 in the PH scale, and the most common and financial preferred way of neutralization is adding $Ca(OH)_2$ (calcium hydroxide). The rise of the waste mixture's PH to more neutral levels or even slightly base levels has as a result the reduction of the organic load and the removal of a large percentage of floating particles such as polyphenolic compounds, protein substances and olive fats. More specific, adding 2-3% of calcium hydroxide achieves reduction of 27.6 % of floating particles, which is impressive given the simplicity and the cost effectiveness of the method (Paraskeva, Zagklis, Arvaniti & Papadakis , 2012).

ii) Flocculation

Flocculation is called the wastewater treatment process in which, chemical or natural flocculants are added in the wastewater, in order to cause the floating particles to clump together and form bigger flocs and eventually settling down on the bottom of the tank. In most cases, alum or ferrix is added in the Wastewater and due to their positive charge, act like magnets on the negative charged organic and inorganic suspended particles. This method is also used as a reprocess method and although it has respectable reduction of COD values on the OMWW mixture, the incineration method is preferred over Flocculation due to its relative cost efficiency when large volumes are treated (Tezcan et al, 2006).

iii) Oxidation

A large variety of wastewater concentrations, including toxic substances, can be partially or completely neutralized with the use of redox reactions. The chemical oxidation method uses hydrogen peroxide (H_2O_2) in order to reduce COD and BOD values and on top of this, to dissolve the organic and inorganic pollutant load. The process and results of oxidation can be magnified, if used, in combination with Ultraviolent radiation. This method is rarely used for the treatment of OMWW due to the large quantities of hydrogen peroxide needed for the treatment of wastes with high organic concentration loads. On top of that, after the oxidation process has taken place, due to the chemical residue remaining, the wastes cannot be processed any further using the biological treatment method.

4.4 Advising the optimum treatment method

In order to provide optimum implementation technology advice, it is necessary to account in a multi-fold manner: a) be effective in the reduction of the COD values, b) provide an overall effective solution, c) be environmentally and socially acceptable. In addition, financially viability must be ensured through relatively low operational costs. In order to have a better visual comparison, a collective table is presented below with the mean COD reduction percentage and cost per ton reduced between Physiochemical and Biological treatment methods ***(table 6)***, (Paraskeva *et al,* 2012). Physical treatment methods are not considered because none by itself can reduce the organic load substantially and are more applicable as OMWW preprocessing methods.

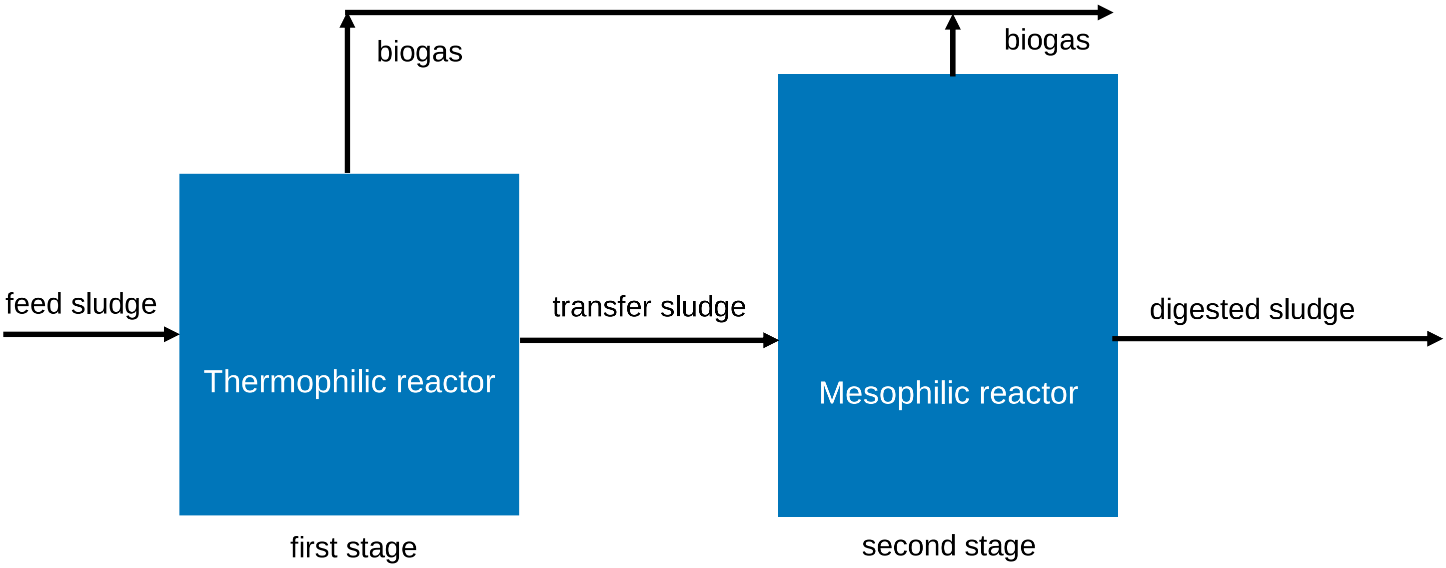
Table 6. Collective OMWW treatment method comparison

Treatment method	Mean COD reduction (%)	Mean phenols reduction (%)	Cost per ton COD reduced (€)
Filtration	97.7	98.3	250
Aerobic treatment	77	79	450
Anaerobic digestion	68	54.5	300
Neutralization	42.5	72	200
Flocculation	46	64.2	100
Oxidation	72.5	98	5.500

For our business proposal we suggest the Anaerobic digestion (AD) method, as it’s the only method that makes any financial sense, due to the reasonable cost of waste treatment and also the capability of bio-methane production. On top of that, it has relatively low operational costs as it is energy self-sustained and the olive water wastes produced in the oil mills of Crete are more than suitable to be used as input. It also fulfills the environmental and societal criteria.

More specific, the AD technology that we are proposing is the Up flow Anaerobic Sludge Blanket (UASB) reactor and specifically the two phase UASB reactors as it is a more advanced method and has lower retention time period (15-20 days instead of 40 days). On top of that, it is a technology that has been excessively developed over the years and although is not the most efficient production method and does not yield the highest rates of methane production in comparison with other prototype technologies. It has 100% availability and significantly bigger BOD and COD reduction values (85-90%). The proposed two phase UASB main facility operating chart flow is presented below **(figure 20)**, (Mainardis, Buttazzoni & Goi, 2020).

Figure 74. Two phase UASB chart flow



5. BUSINESS PLAN PROPOSAL

5.1 General description

As described above, we are going to assess the construction and the financial evaluation of a central OMWW treatment plant on the island of Crete, which utilizes the two phase Up flow Anaerobic Sludge Blanket reactor technology. In order to achieve an holistic approach, some estimations and decisions on some key input values are needed to be made.

5.1.1 Available Biomass input

As stated in chapter 2, the island of Crete produces an average of 100.000 tons of olive oil per year. Given the fact that 80% of active olive mills on the island are three phase mills, which produce wastewater in a ratio to oil of 5/1 (5 kg of wastewater for every kg of olive oil), it is estimated that 500.000 tons of wastewater are produced every year. Almost half of this amount is wastewater from the washing phase, with low values of COD/BOD, which can be cleaned and reused while the other half contains high values of COD/BOD which is necessary to be treated. So, it is estimated that the total available and profitable liquid biomass on the island for treatment is 250.000 tons per year (2.5 kg of wastewater for every kg of olive oil).

Despite this fact, it would not make any financial sense to acquire the total of this amount, not only due to the high transportation costs, but also due to the cost of the facilities needed to accumulate this amount. Instead, the available liquid biomass per region is going to be estimated based on the location of installation, the size and the capacity of the facilities. According to the latest information given by the Association of Cretan Olive Municipalities (ACOM) about each of the island's regions mean annual olive oil production volume and by applying the 2.5 multiplier of profitable wastewater volume, available amount for each region can be determined **(table 6)**.

Table 7. Mean volume of olive oil and OMWW per region

Region	Annual Olive Oil production (tons)	Available OMWW (tons)
CHANIA	30.000	75.000
RETHYMNO	10.000	25.000
HERAKLIO	45.000	112.500
LASITHI	15.000	37.500
TOTAL	**100.000**	**250.000**

5.1.2 Location

Based on this information, it is evident that the best location for the installation of the plant is in the region of Heraklion. This makes sense, as this is the region with the most olive oil mills and accounts for almost half the total volume of olive oil and OMWW production. At this moment, choosing the optimal location is the only way to minimize the transportation cost. Additionally, for this reason the facility should be built near the central roadway and be easily accessible to large transportation trucks. On top of that, the facility should not be installed near populated areas or areas identified as tourist attractions, to avoid creating noise, air pollution and disturb in any way the social welfare as it will have a negative perspective for the company. Given these parameters, we propose the area west of the island’s capital, called Linoperamata which concentrates all the above characteristics and is also near the central power plant which will potentially make the connection to the central electricity grid infrastructure, easier and significantly less expensive.

Having selected the installation area, we can assess the target annual OMWW handling volume. Realistically, a large percentage of oil mills are located in distant and mountainous villages, which makes transportation and business coordination extremely difficult and expensive. Additionally, not all oil mills are going to be willing to cooperate immediately. Therefore, our target volume will be 50% from the total volume produced in Heraklion from near and accessible mills, 25% from the total volume produced in Lasithi, and 25% from Rethymno summing up for a total of 100.000 tons of OMWW.

5.1.3 Size of main facilities

Knowing the target OMWW annual input volume, we can estimate the size and the facilities needed for the operation. In real-world applications, size depends on more than just the annual volume number. The size of the main digester unit depends on:

- The type and characteristics of the organic waste that is going to be disposed in the digester.

- The objective of treating the organic waste (production of energy/heat/ organic fertilizer).

- Characteristics of the soil and air temperature in the installation area.

The digester size can be defined as the total size of the biogas unit, which contains the size of any volume occupied by the digest material and the volume of gas storage. According to Samer (Samer & Kumar, 2012) the mathematical equation which describes the optimum size is:

Digester size (m^3) = Daily feed-in (m^3/days) x Retention time (days) (1)

We assume a daily feed in volume of 500 tons of wastewater sludge per day with continued feed and retention time set to 15 days. The minimum for a twin phase UASB reactor retention period (15 days) is achievable if the digester is kept on stable temperature of 42℃ degrees during operation. Therefore, we estimate the total size of the digester to be 7500 m^3. The follow-up second stage digester will have the same volume capacity (7500 m^3) as well. Both these facilities would be built partially underground in order to save space and also provide better and more efficient insulation with minimum heat loss. Although these facilities will be fully equipped with an extra insulation layer in order to minimize any heat exchange with the environment, the general warm climate of the Mediterranean region provides a good basis for minimum heat loss and more efficient heating process.

The annual operating hours of the plant is set at 7.500 hours per year, which are equivalent to approximately 10 months. This value was estimated, calculating the 40 days initial retention time which are needed in order to start the anaerobic digestion process and the 7.5 months working period of the olive oil mills in Crete. For the continuous operation of the plant during the remaining one month 5 OMWW storage tanks will be built with capacity of 2.000 tons each. A great benefit of the OMWW treatment process is that the sludge can be stored for future use. Also, the option will be available to store specific types with different characteristics of OMWW in different tanks in order to add if needed to the main digester, so as to achieve a stable and homogenous mix when needed. As previously described, the actual volume of biogas produced by the Anaerobic Digestion process is heavily depended on the composition and the organic load of the mixture, which is not a stable constant, being able to adjust the mixture with already stored OMW sludge of different compositions value, will result in a more achievable stable biogas production volume.

5.1.4 Plant's outputs

Although the exact volume of biogas produced in the plant is very difficult to predict accurately, based on literature data, experiments that took place and the data of ongoing two phase-UASB plants in the Mediterranean, it is estimated that the volume of biogas could be maintained at a rate of 0.4/m^3 per ton per hour. This will result in a biogas volume production of 200 m^3 per hour. The biogas that is produced during AD consist of 65-70% methane (CH4), 30-35% carbon dioxide (CO_2) and 1-5% other gases such as H_2, H_20, N_2, NH_3, H_2S. The latter can be used to produce Sulphur which can then be sold, but due to the minimum quantities that will be produced, the insignificant revenues and the cost of transformation it is not included in the business plan and in the financial model. Instead, it will be burned as if not treated, due to its characteristics, it can corrode the interiors of the CHP engines. The produced CO_2 can be either burned to produce heating which can be exported or released into the atmosphere. Releasing it back to the atmosphere is chosen as heating demands of the facility and the market demand for heating will be covered completely by the CHP output. On top of that, The CO_2 released in the atmosphere already exists in the organic mixture and is formed naturally, so there is no additional CO_2 pollution added to the environmental footprint, and so it will be used again by nature to form plants, vegetation etc. Finally, the remaining percentage is translated to 140 m^3 of methane per hour. The consumption of methane for a CHP unit is 0.025667 m3/kW or 25,667 m^3 per MW so this is enough to power a total 5.5 MW CHP unit (Abbasi, Deymi, Mahdi, Gord, Mahmoof, Abbasi & Sepide, 2015).

Instead of just operating a single CHP unit of 5.5 MW, the variation of a pair of 2 MW CHP engines and three 500 KW CHP engines is proposed. The reason is that in case of a malfunction or a secluded service by the manufacturer, there is no need to halt the production completely as it would be time consuming and costly to restart the process. The SCHNELL manufacturer is chosen for our CHP system supplier. The 2 MW model (MAXI 2000) has an overall efficiency of 87.9% (43.4% electricity efficiency, 44.5% thermal efficiency and 12.1% energy losses). The 500 KW model (FLEXI 530) has an overall efficiency of 82.7% (41.3% electricity efficiency, 41.3% thermal efficiency and 11.3% energy losses). According to this data, it is estimated that a combined total of **17.676 MW electrical power** (13030 KW_e from the 2 KW/h CHP Units and 4646 KW_e from the 500 KW/h CHP units) and **18.000 MW thermal power** can be produced, which is translated in 64.800 GJ (13350 MW_{th} from the 2MW/h CHP Units and 4646 MW_{th} from the 500 KW/h CHP units) (Tedom Schnell, 2021).

Additionally, the digested mix that outflows for the Anaerobic treatment proceed is going to be exploited and handled. The remaining residue, according to the literature data, contains a mean value of 15 kg of solid mass per sludge tone. This mass will be used to produce organic fertilizer and be sold to farmers and agricultural producers. In order to extract this mass, the remaining wastewaters will be treated into two lagoon facilities. The results of this method, would be enhanced by the warm climate of the island and accelerate the evaporation process. The remaining residue will have very low to none pollutant load and will be safe to evaporate into the atmosphere posing no threat to the underground aquifers. It is estimated that the annual volume production of the organic fertilizer will reach 1500 tones. Finally, a collective overview of the estimated values and assumptions used for this business model scenario is presented in the table below **(table 7)**.

Table 8. Input data for assumptions and assessments of the business model scenario

DESCREPTION	VALUE	M.U
Lifecycle of the investment	15	years
Available biomass (OMWW) on the island	300.000	tons
Annual handling volume	100.000	tons
Daily feed in volume	500	tons
Digesters volume capacity	7500	m^3
Annual Operating hours	7500	h
Annual Biogas production	1.500.000	m^3
Daily Biogas production	4.800	m^3
Biogas production per hour	200	m^3
Biogas consistance	70% methane 29% carbon dioxide 1% other gasses	%
Annual methane production (CH4)	1.050.000	m^3
Daily methane production (CH4)	3.360	m^3
Methane production per hour (CH4)	140	m^3
Annual carbon dioxide production (CO_2)	435.000	m^3
Technical characteristics of the CHP systems		
2 MW CHP Systems	2	units
Methane consumption per hour	25,667	m^3 / MW
Overall efficiency	87,9	%
Electricity efficiency	43.5	%
Thermal efficiency	44.5	%
Energy waste	12,1	%
Annual electricity production	13030	MW_e

DESCREPTION	VALUE	M.U
Annual thermal production	13350 or 48.060	MWth or GJ
500 KW CHP system	3	units
Methane consumption per hour	25,667	m^3 / MW
Overall efficiency	82.6	%
Electricity efficiency	41.3	%
Thermal efficiency	41.3	%
Energy waste	17,4	%
Annual electricity production	4.646	MWe
Annual thermal production	4.646 or 16.726	MWth or GJ
Total CHP systems installed	5.5	MW
Total annual electricity production	17.676	MWe
Total annual thermal production	18.000 or 64.800	MWth or GJ
Plants self-consumed electricity (percentage)	20	%
Annual Plants self-consumed electricity	3.535,2	MWe
Plants thermal needs (percentage)	35	%
Annual Plants thermal needs	6300 or 22.680	MWth or GJ
electricity sold (percentage)	80	%
electricity sold	14.141	MWe
Thermal energy exported (percentage)	65	%
Thermal energy exported	11.700 or 42.120	MWth or GJ

DESCREPTION	VALUE	M.U
Solid available biomass per tone	15	kg
Total organic fertiliser produced	1500	tons

5.2 Funding

The substantial capital needed for a UASB OMWW treatment plant installation is one of the most important factors that cannot be easily overcome and has withheld the materialization of numerous investment ideas. In order to provide the best chances of success for the required funding and the significant initial capital needed for this investment, the full use of own capital or a business loan from traditional financial institutions is not proposed. For the first one, the reasons are mainly the difficulty of raising and committing this amount and the problem of liquidity that is created by doing so. For the second one, the reason is simply that, after the global financial crisis, banks have regulated their business loan approvals to only well assured and established firms, and even if a loan was successfully secured, the interest that has to be paid with the instalments would be substantial and undoubtedly would constitute a large risk, especially in the early stages of the business endeavor, where 80% off all start-ups fail. Therefore, it is suggested that equity finance through the institution of angel investors is the more appropriate mean of funding this type of start-up (John, Jeffrey, Sohl, William & Wetzel, 1995).

An angel investor (or business angels, private investor) is an individual or large investing firms that provide the financial resources for a company start-up or expansion. Even though venture capital funds are usually bigger than angel investments, according to the latest publications, the past decade the total investment by venture capital is quantitatively smaller than angel investments. Angel investors agree to fund and invest their money in infant start-ups because they seek more profitable and better investment alternatives than the traditional ones, such as stocks, bonds, etc. In many cases though, Angel investors do not just look for a way to increase their financial assets, but also for their personal satisfaction, achievement and fame that a successful business move and investment will provide them. For those reasons, angel investors want to correlate their names or firms, with alternative green and eco-friendly technologies and businesses, as not having in their investment portfolio such companies reflects negatively in their social image and market value. The proposed idea goes hand in hand with all the above values and targets, but not only that, angel-investors are also aware that 80% of the start-ups that they invest in, fail in the first stages, so they are willing to invest more time and provide their expertise in order to overcome this difficult phase. They also possess large and deep understanding of the business environment, as well as market knowledge. Apart from their funds, Angel investors also provide their experience to help in the long-term sustainability, a factor that will contribute positively on the success of the proposed business idea (Kerr, Lerner & Scholar, 2010).

5.3 Market analysis

Understanding, the environment in which the company is going to operate is a crucial factor which defines business success or failure. For this reason, the macro environment (political, demographical, economical, technological, socio-cultural) and micro-environment (customers, suppliers, competitors, substitutes) of the proposed business are going to be analyzed.

5.3.1 Macro environment

i) Political forces

The political forces in the macro environment reflect on the laws and the regulatory frame that sets the restrictions and the opportunities for the businesses that operate in each market. For Greece, the general guidelines and framework are set directly from the European Union. More specific, for the renewable energy market, the EU has published the Renewable Energy Directive 2009/28/EC which requires each country to produce at least 20% of their total energy needs with renewable sources. This has forced countries to adopt and provide market incentives for investments in the RES market. Greece in 2016 published the regulatory support mechanism for electricity generation from RES under the Law 4414/2016. According to this Law, priority is given for the injection of electricity from RES into the electrical grid. The electricity produced has been remunerated by a technology specific feed-in tariff (FIT) and the payment of the FIT was guaranteed for a period of 20 years (until 2036) with an extension proposal still open. The Feed in Tariff and the RES support scheme in Greece per plant category and technology are presented in the following table ***(table 8)***, (Energypedia, 2020).

Table 9. Feed in Tariff per plant category and technology

RES technology/capacity category	Reference Tariff (€/MWh)
Wind installations in the interconnected system	98
Wind installations on the non-interconnected islands	98
Small Hydro ≤ 3 MW	100
3 MW < Small Hydro ≤ 15 MW	97
Solid Biomass (or bio-liquids) exploited through thermal processes except gasification, from stations with installed capacity ≤1MW (excluding the biodegradable fraction of municipal waste)	184
Solid Biomass (or bio-liquids) exploited via gasification process from stations with installed capacity ≤1MW (excluding the biodegradable fraction of municipal waste)	193
Solid Biomass (or bio-liquids) exploited through thermal processes from stations with installed capacity 1MW 5MW (excluding the biodegradable fraction of municipal waste)	140
Gas from landfills and biological sewage treatment plants and biogas from anaerobic digestion of biodegradable material of wastewater and sewage sludge ≤ 2 MW	129
Gas from landfills and biological sewage treatment plants and biogas from anaerobic digestion of biodegradable material of wastewater and sewage sludge > 2 MW	106
Biogas from anaerobic digestion of biomass≤ 3 MW	225
Biogas from anaerobic digestion of biomass> 3 MW	204

Solar thermal stations without storage	257
Solar thermal stations with storage (min 2 hours)	278
Geothermal stations ≤ 5 MW	139
Geothermal stations > 5 MW	108
Other RES (including energy recovery plants utilizing the fraction of the biodegradable municipal waste falling outside another category of the table that meet the requirements of the current European legislation)	90

The financial and revenue analysis of the proposed business plan was calculated according to this data, as well as the lifespan of the investment which has the duration of the active window of the FIT directive. If the scheme is extended in the future, the initial stated 15-year lifecycle of the investment will be re-evaluated. Finally, the legal form proposed for the company to take is Private Company “P.C” which has a flat tax rate of 24%.

ii) Demographical forces

Demographical forces play a significant role in the market analysis of any business. One of the most important factors is migration. If a sudden reduction in the population of the island of Crete takes place, it will affect the overall demand for electricity and eventually the demand and value of the product. According to the latest statistics forecasts, this threat is not only invalid, but on the contrary the population of the island shows an even higher growth which will increase the demand for electricity on top of the already estimated increase due to the technology developments and change in lifestyle needs. Furthermore, there are two other crucial variables that play a critical role in the viability of this proposal. The first variable is the number of olive oil producers and the overall agricultural market development. The second one, is the availability of engineers and workforce that will be occupied and collaborate for the project.

The first variable is important because a hypothetical reduction in the number of olive oil producers and people that engage in the agricultural activities, will mean less olive oil produced and thus, less olive oil mills will be active, that will result in a shortage of OMW, which is the input raw material for our electricity production. Despite the fact that a possible reduction of OMW will have a positive impact on the environment, a reduction in the olive oil production is not the optimum and wanted way of achieving environmental sustainability and this will have a reduction in the overall well-fare of the islanders. Such hypothesis is unlikely to happen, considering the agricultural history and conditions of the island (favorable climate, landscape, fertility, ongoing agricultural investments and production). On top of that during the financial crisis in Greece, the statistics showed a shift of the islanders to the agricultural sector with its growth index rising substantially. If the positive estimations of the Association of Cretan Olive Municipalities (ACOM) for a rise in olive oil production in the next years is also considered, the deduction can be made that there is no threat to the business plans' estimations of supply in the investment lifecycle.

For the second variable, the island of Crete has the fortune to host one of the best Technical Universities in Europe, which has excellent engineering graduates in all fields (production management, mineral resources, environmental and electrical and computers engineers) a great percentage of whom are permanently based on the island. This means that the appropriate staff will be easily found to collaborate with and work in the facilities. Due to their excellent academic knowledge, not only less training is needed and thus less time consumption and expenses, but they will also be an asset of great value for the company.

iii) Economical forces

The economic forces describe the general economic situation of the market and the economic stability and characteristics of the country's economy in general. It is no secret that Greece was facing a large economic regression from 2008. The unemployment rate has gone up, the money supply has been reduced and the available income of citizens has been shrinking in comparison with other EU Country-members. Although it may seem that Greece does not provide the optimal environment for business success, in reality the past year it is obvious that Greece has stabilize its economy and with the supervision of the EU provide a stable and secure environment for investments.

On top of that, The EU has allocated significant resources and provides a well-structured frame in order to counterbalance the inefficiencies that each country-member's economy has, in order to provide a fair and competitive market across its regions. Evidence of that can be seen in the recent EU commission meeting, where the strategy for regional development was decided for the upcoming years (2021-2027). According to that, the strategy is going to focus on 5 pylons, one of those is the environmental sustainability and in the RES market. For that reason, EU has committed more than 60 million that are going to be distributed in form of subsidies. Subsidies are important factors of financial aid that reducing the cost of ownership and make the investment more sustainable and less expensive. A subsidy regime was not mentioned in the funding proposal nor the political forces of the macro environment analysis due to the fact that to hasn't yet been issued in a Law form. What is important in this stage of analysis is the general guideline and willingness of the EU to help investments and accelerate the growth of the energy market in general. A market that is already been reaching new heights year by year and currently stands at 600 TWh of renewable energy supply.

iv) Technological forces

The technological developments in the market can have an immediate effect on the business and the strategy. A disruptive new technology can cause a threat for the existence of the company, especially in the RES market where new innovations and technologies are exploited with an unprecedented rate. On the other hand, the introduction of a new technology can also mean a positive development and an opportunity. Due to the nature of the market, the developments in the research stage and in the market must be constantly monitored in order to adapt the business model and the strategy if necessary. Overall a technology breakthrough in the RES market will be beneficial to the consumers, the environment and the total well-fare. For the case of the island of Crete, the demand and necessity for renewable energy is far from saturated. New disruptive and incremental technology implementations on the island, will give value to the company, as well as help with the energy independency and environmental sustainability of the island.

v) Socio-cultural forces

Social and cultural forces link to factors that affect society's values, preferences and behavior. It is believed that the business model and the proposal is in line with the above factors and will have a positive acceptance by the people of the island, as the pollution on the environment and the ecosystem will be reduced and a solution to the OMWW management problem will be provided, as well as an efficient and clean energy production system and overall assist the traditional and valued olive oil activities of the island. Despite this fact, it is inevitable that there will be some resistance and negative perception in the early stages of the construction of the facilities due to the fears for noise and air pollution. Therefore it is important to communicate the goals, vision and strategy which ensures that not only this problem will not occur but also, that it will have a positive impact on the environment.

5.3.1 Micro-environment

In addition to the analysis of the wider macro-environment, a comprehensive analysis of the competitive micro-environment is necessary in order to define and shape a complete strategy using the Porter analysis *(Porter M., Competitive strategy. NY: The Free Press, 1980)* which defines the structure of the competition into five forces, the competitors, the custumers, the substitutes, the competitors and the threat for new competitors to enter the market (Porter, 1980).

i) Suppliers

Firstly, the broad category of our suppliers will be, by definition, the numerous three phase Oil mills located on the island. Although the OMWW form an unwanted burden for the olive mills and in other cases are given without cost, the main purpose is for it to be purchased. By providing this incentive, the intention is to form contacts with the oil mills, so as to be provided throughout the lifecycle of the investment with the necessary input, attract the cooperation of more suppliers and try to eliminate practices such as disposal to the environment of the harming wastes. Lastly, when the supplier has a key role to the production process, they usually have very big influence and negotiating power. In this case, this poses no threat due to the fact that there is a very large number of suppliers who are relatively small in size. Additionally, contracts with the transportation service suppliers must be formed. Choosing to form partnerships with transportation companies and not investing in purchasing the needed assets, will keep the initial capital investment needed relatively lower. Again, multiple suppliers will be hired but due to their limited number, the possibility of gaining substantial negotiating power must be taken into consideration. Finally, the last major supplier would be the technology provider. ZORG Biogas Company is chosen as the contractor as it will not only provide the technology but also design and built all the facilities of the plant. This will be a long-term partnership as according to their business model, they also include the construction cost, the necessary maintenance and services for the facilities and equipment throughout the lifespan of the plant.

ii) Customers

The customers are the most important focus point of any business. Our products target two market segments, the electricity market and the fertilizer market. For the electricity market which will be the main market, despite the fact that the end user would be the typical households on the island, the sole customer is the Public Power Corporation (DEI) and by extension the Government State itself. The state owns 51.12% of the corporation and is responsible for its management. Having the state as a customer gives the company great benefits and ensures stability and full coverage of the supplied quantity. However, it also entails serious threats. More specific, the Greek Government was forced during the economic regression to privatize a large percentage of state-owned companies and organizations. This could happen again in case of a future regression and could result in a complete private ownership of the Power Corporation with unknown practices and strategies, while at the same time the new players will have the complete negotiating power over our product.

The second customer segment is the agricultural farmers market. Unlike the first market segment, the Green Fertilizer market has great diversity and a large number of potential customers, addressing the needs of agricultural farmers and even the home gardening market. Although, the market and the potential profits are much smaller in size and in revenue than the company's main one, it plays a significant role in the company's intangible assets (fame, customer perception, values).

Finally, there is also the potential industrial heating market due to the production of heating through the CHP system, but due to the lack of infrastructure on the island and the large cost of constructing ourselves the necessary heat transferring grid, it will remain unexploited for now. If market conditions or the state's investment in the infrastructure on the island change, the company's heat product could be potentially sold to the factories, greenhouse facilities and households for covering their basic heating needs or even the Public Power Corporation which uses heat to generate electricity. Currently the demand is not high enough to even consider such an endeavor, but the market will be constantly monitored for any changes or shifts.

iii) Competitors

There are no competitors to be considered for the OMWW treatment and managing market as the plant will be the first on the island. Despite this fact, it will not be characterized as a monopoly as it will have a positive impact on the economy and the ecosystem environment of the island. In other words, the construction of the plant will benefit all aspects on the island in comparison to a non-construction hypothesis and thus, it is compliant to the laws of EU about fair and equal competitiveness. If the antagonist market is taken into consideration, the competitors would be the Public Power Corporation, which is not only state governed but also one of the main customers and thus cannot be characterized as a direct competitor, and the numerous RES electricity generator facilities installed on the island (windmills, solar panel facilities etc.). Due to the largely unsaturated RES electricity production market, currently there is no threat posed and if the estimations for the rise of electricity demand in the future are taken into consideration, nor will be during the lifespan of this business scenario.

In order to provide a much more complete and detailed market analysis and despite the low probabilities, the possibility of future changes in the structure of competition due to external factors should also be considered. For example, it is possible for the E.U. or Greece to ban three phase oil mills or to give subsidies for converting the existence mills to two phase mills. In this scenario, the input will be changed from OMWW to OMSW as the main facilities are capable of. In this case the company's competitors would also be the pomace handling and olive oil refinery market as they would require the same raw material as our electricity production process. Therefore, again, a close monitor of any market and Law changes is required, in order to secure the necessary input to ensure a smooth production process.

Finally, the competitors in the fertilizing market would be the fertilizing producers who pose a serious threat, but due to the product differentiation of this company, value to the customers will be given and the provision of an eco-friendly alternative to conventional fertilizers with minimum CO_2 production footprint and in an a lower and more competitive price.

iv) Threat of new competitors entering the market

In the open market, there is always the danger of new competitors entering and acquiring a percentage of the market. The market of renewable energy and electricity generation in Crete is not composed of great market barriers and is an attractive investment in all RES fields. Specifically, for the OMW market, the two greater barriers are the initial capital investment needed and the guarantee of the necessary wastes for the production process. Despite the difficulty of acquiring the initial capital, the possibility of another individuals or firms, finding the resources and investing in the same idea cannot be ruled out. On top of that, despite the fact that the annual production of OMW is limited on the island, realistically we cannot acquire and handle all the wastes as it will be unprofitable and infeasible. That is why in both cases, it is necessary and crucial to be the first to infiltrate the market and have the initiative regarding the selection of the location of the facilities and oil mill supply contracts, which will minimize the cost of transport and give the best chances for business success, always in respect to E.U. fair and equally competitiveness laws and directives.

v) Substitutes

The substitutes analysis does not particularly differ from the competitor’s analysis. For this reason, the focus will be on the market and business consequences that a potential connection of the island of Crete with the central electricity grid infrastructure will bring. The connection plans have been announced by the government and are currently underway. This means that the power plant of the island will gradually lower its electricity production and only serve as a distribution node for the supply of electricity throughout the island. This will result in less pollution and less expensive electricity. Despite the advantages that this development will have, it will only partially and temporarily reduce the energy problem and its negative effects on the island. The central grid still depends heavily on fossil fuels and although it will not pollute as much as the islands’ plant, it will still pollute respectively other areas of plant installations which will only worsen as the production volume will rise to cope with the electricity demands of the island. For this reason, it does not pose any serious threat to endeavor this business and the market strategy, as a complete RES energy reform on the island is necessary to utterly solve the energy dependence problem and achieve environmental sustainability. On top of that, our proposal also tackles the oil mill waste management problem on the island and contributes to both problems substantially.

5.4 Financial Analysis

5.4.1 Cost analysis

The initial cost analysis of the suggested business investment was estimated according to information and quotes from the technology provider and suppliers and by analyzing similar in size ongoing Up flow Anaerobic Sludge Blanket (UASB) plants. Hence, from this research it is concluded that the cost in comparison to a smaller AD plant is not significantly higher and the scale up of the facilities yield a higher cost to benefit ratio. The estimations are summed up in the following table ***(table 9)***.

Table 10. Initial investment cost estimations

Expense Name	Expected Cost (€)
Digesters and supportive facilities	3.400.000
Combined 5.5 MWh CHP systems	1.000.000
OMWW storgage tanks	1.000.000
Lagoons facilities	300.000
Land acquisition (8 acres)	400.000
Internal Gas network	250.000
heating and insulation	250.000
Connection to electricity grid	30.000
Total hardware (including the control room)	800.000
Advices and permits	20.000
Biogas Separator	20.000
Torches	17.000
Construction and Labour	1.000.000

5% unexpected costs, price inflations, hardware failures etc.	424.350
TOTAL INITIAL INVESTEMT	**9.000.000**

5.4.2 Annual economic analysis

Table 11. Annual revenues and expenditures

DESCREPTION	VALUE (€/year)	RATIONALE
Revenues from electricity sold	2.272.764	11.141 Mwh x 205 €/Mwh
Revenues from organic fertiliser	3.000.000	2 €/kg x 1500 tons
OMWW transportation cost (including purchase cost)	1.500.00	15€/ton
Solid digeste handling and storage cost	500.00	
Facilities and equipment maintenance	100.000	(this applies to assets that don't include a maintenance agreement with the purchase contract)
Personnel salary	150.920	11 employees x 14 monthly salaries x 980 €/month
Operating and Management cost	700.000	
Incurance	100.000	
Total annual revenues	5.272.764	Revenues from electricity sold + Revenues from organic fertiliser
Total annual expenses	3.050.920	

DESCREPTION	VALUE (€/year)	RATIONALE
EBITDA (Earnings Before Interest, Tax, Depreciation, and Amortisation)	2.221.844	
Depreciation	400.000	straight line depreciation is assumed (9million initial cost - 3million residual value)/15 years of tangible assets lifecycle
taxable revenues	1.821.844	
24% tax	437.243	
Annual net profit	**1.784.601**	

5.4.3 Financial viability

In order to evaluate the financial viability of the investment, a techno-economical analysis will be performed using the investment performance indicators of the Net Present Value (NPV) and the Internal Rate of Return (IRR).

i) Net Present Value (NPV)

The Net Present Value of a time series of cash flows is defined as the sum of the present value of each cash flow minus the initial cost of investment. In other words, NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. If the NPV is positive the investment is acceptable, if negative the investment is rejected and if zero, we are indifferent. The formula to calculate NPV is the following:

$$NPV = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t} \quad (2)$$

where:

R_t = Net cash inflow-outflows during a single period *t*
i = Discount rate of return that could be earned in alternative investments
t= Number of times

In our investment proposal:

R_0 is the initial investment of -9.000.000 €
R_{1-15} is stable at 1.784.601 €
t= 15 years i = 4% which is the interest of long-term business deposit investment in Greek banks, according to the Bank of Greece at the time of author (October 2020).

According to this, our NPV is calculated at **10.841.855** € which in not only positive (acceptable), but also highly attractive as an investment scenario.

ii) Internal Rate of Return (IRR)

The internal rate of return is a rate of return that is used to compare and measure the profitability of an investment. More specifically, the IRR of an investment is the discount rate at which the net present value of the positive cash flows, equals the net present value of the costs. If the IRR is higher than the equivalent return rate of an alternative investment or the cost of capital, it means that the investment is profitable and it makes sense to go through with it. The formula to calculate IRR is the following:

$$0 = NPV = \sum_{t=1}^{N} \frac{C_t}{(1+IRR)^t} - C_0 \qquad (3)$$

where:

C_t =Net cash inflow during period
C_0 = Total initial investment
IRR = The internal rate of return
t = The number of time periods

In our investment proposal the internal rate of return is **18**% which is not only higher than the 4% interest of a long-term business deposit investment, but also higher than the majority of investment products in Greece. Therefore, it makes an attractive addition to any investment portfolio.

5.5 Sustainability

Although, many companies tend to set their main goal in creating wealth and profits for stakeholders, we intend not only to focus on monetary profits, but also include equally two other performance areas, the social and the environmental impact of the company. For that reason, the **triple bottom line** approach will be adopted, focusing and measuring not only the financial outcome, but also the impact that our company makes on people and the environment. This approach is selected primarily because of the nature of the proposed business plan and the value proposition, which as stated concerns the conversion of oil wastes into renewable sources and which by itself has a positive impact on the environment. Another equally important reason was to better understand and draw an holistic picture of the full cost of developing such a business. By embracing our corporate social responsibility and focusing equally in all three performance areas (financial, social and environment), the long-term sustainability will be increased (Welford, 2006).

It will be irresponsible to draw a business proposal that will have as its corporate vision the environmental sustainability and not mention and measure the negative impact of the company on the environment. The main negative consequence is the pollution and the release of CO_2 to the environment due to the constant transportation of OMWW to the facilities. It is estimated that the transportation trucks will produce around 6.000 thousand tons of CO_2 annually. This means that the average pollution per MWh produced is 0.53 t CO_2. According to research published by the Joint Research Centre of the European Commission, the average pollution for a MWh produced in lignite fuel power plants in Greece is 0.90 t CO_2. As a result, the carbon footprint is positive and by adding the electricity production to the electrical grid balance of the island, a reduction of 4000 tons of CO_2 emissions will be achieved (Koffi, Cerutti, Duerr, Iancu, Kona & Janssens-Maenhout, 2017). On top of that, the social welfare of the people on the island as well as the environmental sustainability will be further improved, by substantially reducing the volumes of OMWW that are disposed in the environment polluting the ecosystem. This waste management solution will give added value to the company and although it is difficult calculate how much in monetary terms, we are confident that making a positive impact socially and environmentally, will further increase the market value.

Finally, it is important not to settle with positive socio-environmental results, but also adopt throughout the lifecycle of operation, the concept of business model innovation (BMI) (Carayannis, Sindalakis & Walter, 2015). By constantly re-evaluating the business model plan and pursuing new ways to create and deliver value to the customers and the company, the business sustainability and the market position of the company will be increased and straightened. Focus will be given on innovating and developing new revenue streams and distribution channels, such as exploiting the capabilities of the plants of digesting and processing not only OMWW but also solid wastes, as well as the better utilization of our heat producing capabilities. Moreover, in the near future the market availability and the financial feasibility of investing in purchasing the company’s own exclusively electrical transportation trucks will be examined. With this action not only will the company be able to provide a green solution to the transportation of the wastes, but also reduce the largest variable cost. A second step to this direction, would be to analyze whether it is technically possible to connect the near radius olive mills directly to the company’s facilities using underground pipe networking in order to transfer the OMWW without the use of any other traditional transportation means. This will require, dedicated centrifugal separators to be installed in the chosen oil mills, to fully reduce any solid materials present in the wastewater mix and avoid any type of pipe blockage due to solid residue concentration. If proven to be achievable, this action will significantly improve both the cost and the CO_2 emission of OMWW transportation.

5.6 S.W.O.T. analysis

STREGNTHS	
DESCRIPTION	**RATIONALE**
Favorable competitive, regulatory and societal context	The business plan excels in all 3 aspects as it is very competitive, the regulations are changing in favor of renewable energy technologies and also fits perfectly in the societal context as more and more people realize the benefits and the social gains renewable energy offers.
First to penetrate the market	From the business perspective, being the first to penetrate the market will give as a competitive advantage over the potential future competitors and also, provide the best chances for business success due to the fact that we have the ability to select the location, business partners and suppliers first.
Provides a necessary OMWW management solution to the island of Crete	By providing a solution to the OMWW management problem and also an efficient and clean energy production method, it will not only give market value to the investment, but also substantially assist the reduction of the ecosystem pollution and overall assist the traditional and valued olive oil activities of the island.
Energy supply independence	The facilities will be able to self-supply both its electricity and heating needs, thus making our business more sustainable and less vulnerable to external factors.
Technology availability	The two phases Up flow Anaerobic Sludge Blanket reactor technology is 100% available and has

STREGNTHS	
DESCRIPTION	**RATIONALE**
	incrementally improved, which will allow the company to operate with significant profits, thus making the investment viable and profitable.
High Net Present Value and IRR rate	Both these rates are highly positive and indicate a profitable, sustainable and attractive investment.

WEAKNESSES	
DESCRIPTION	**RATIONALE**
Substantial initial capital is needed	The more capital in need to be invested, the less attractive the investment and more difficult to find investors willing to do so.
Inconsistent volume of biogas production	The volume of biogas produced by the Anaerobic Digestion process is heavily depended on the composition and the organic load of the mixture which is inconsistent.
Dependence by the volume of olive oil production on the island	There is a correlation of the production process with the overall olive oil production volume, which by nature is vulnerable to external factors such as (extreme weather, olive tree diseases etc. If the annual olive oil production volume is reduced, it will have an immediate effect on the OMWW volumes available, which is our raw material input and thus on the volume of our production outputs.

OPPORTUNITIES	
DESCRIPTION	**RATIONALE**
Window of opportunity is open and will remain open long enough to capture value	There is undeniable evidence that renewable energy is the future and the only option for a sustainable energy supply. Also, governments and citizens are aware of the need to focus on renewable energy as the main energy source and that is reflected on the new regulations that try to limit/ban the use of fossil fuels and subsidy them with renewable energy sources. Therefore, the window of opportunity is open and will remain open for a long period of time enabling us to capture value.
European Union favorable regulations and directives.	The European Union has understood the necessity for sustainable and renewable energy and has orientated its regulations and directives in order to assist and accelerate not only the RES technologies innovations but also new start-ups that apply these technologies to the European market.

THREATS	
DESCRIPTION	**RATIONALE**
Loss of ownership and company control.	Due to the suggested financial mechanism of angel investors, the market and corporate strategy is dictated by the investor who has complete control over all important decisions and management practices.

6 CONCLUSIONS

Based on the result of the business plan and the techno-economic analysis we can conclude that an investment on the island of Crete, regarding the construction of a centralized Olive Oil Waste Management plant is not only feasible, but also poses a prosperous and attractive investment. The business plan proposal was presented with the sole purpose of investigating the variables of such business endeavor on the island, given the available olive oil waste management technology and its adaptation and implementation feasibility on the Crete's specific conditions and unique characteristics. The Anaerobic Treatment method and more specific the two-phase UASB (Up flow Anaerobic Sludge Blanket UASB) variation, has reached a development level which not only makes sense financially, but also has a significant efficiency improvement. These incremental improvements on efficiency in the biogas production and collection process, have allowed the installation of a 5.5 MW CHP plant for electricity production in the region of Crete, which up until now was not possible due to technological limitations. Although the proposal focuses on the Anaerobic Treatment method, other methods and technology innovations are being developed and exploited with an unprecedented rate, which could also be potentially implemented on the island. Therefore, my suggestion is not absolute and different methods and technologies should be investigated. The most important factor of my suggestion is the benefits this installation will have on the island.

More specific, there are two main important contributions that this investment will have. Firstly, it will play a catalytic role in the reduction of the environmental pollution and ecosystem destruction that is currently taking place on the island due to the uncontrolled and irresponsible Oil Mill Wastewater disposal. At the moment, most of the OMWW are being disposed into the environment due to the financial and technical inability of the small and medium size oil mills to handle and treat them and also due the absence of alternative OMW treatment installation on the island of Crete. This not only enhances the market opportunity and value that an investment in this field will have, due to the fact that the market is relatively virgin and unexploited and will have tremendous strategic advantage by the initiative market penetration, but also highlights the necessity and urgency for an olive oil waste management solution to go through with it on the island. The second factor is that, in addition to the environmental sustainability improvement, an alternative RES electricity generation plant is introduced on the island. This will further assist the ecosystem by reducing the overall CO_2 emissions footprint on the island by substituting a percentage of fossil fuel generated electricity. This will also improve the energy grid balance of the island and will play a significant role in the electricity independency of the island, despite any future interconnection plans with the mainland.

In addition, it is important to underline the direction of the European Union, which has shifted to the renewable energy sector market and has constructed a framework and issued directives, that assist and accelerate the technology innovations and investments on renewable energy sources. Therefore, similar research must be made across the Mediterranean region, where similar conditions with the island of Crete are applied in order to identify the feasibility of such green investments. Although, it is important to analyze the cost to benefit ratio and reassure the financial sustainability of such actions, it is even more important to secure and protect the environment sustainability and apply methods and practices that respect and protect nature from current and future human activities. Finally, it is undeniable that the wastes which are produced by our modern lifestyle strongly oppose to nature's balance and magnify the waste management problem. Therefore, we are obliged to face the consequences of our actions with responsibility and reverse the current situation by using technological progress and breakthrough innovations.

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