

<b>Work Package 5:</b>	<b>Business Plan and related methodology for the energy use of olive residues</b>
<b>Deliverable 5.1:</b>	Greek Business Plan for energy facilities exploiting olive-milling residues
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### 1. Analysis of the availability of depleted pomace in the territory of Chania, island of Crete, Greece

Greece holds third place in world olive production with more than 132 million trees, which produce approximately 370.000 tons of olive oil annually as shown at Table 1. Olive pomace oil potential is estimated based on the assumption that olive pomace oil production is about 8% of the olive oil production (Picture 1)<sup>1</sup>.

**Table 1:** Domestic annual olive oil production (Source: Hellenic Ministry of Rural Development and Food, 2008)

Year	Olive oil production(t)	Olive pomace oil potential(t)	Mean olive oil price (€)	Gross value ('000 €)
2002	414.000	33.120	2,17	898.380
2003	306.940	24.555	2,19	672.199
2004	364.578	29.166	2,57	936.965
2005	367.579	29.406	2,83	1.040.249
2006	335.929	26.874	3,19	1.071.614
2007	419.297	33.544	2,65	1.111.137

**Picture 1:** Map of Greece



**Picture 2:** Map of island of Crete



<sup>1</sup> Olive and olive pomace oil, sector analysis, ICAP Management consultants, Athens, 2009

The island of Crete has the second largest production in Greece after the region of Peloponnese and follows the Aegean and Ionian Islands.

Crete, with a population of 650.000 in year 2005, is one of the 13 regions into which Greece is divided. It forms the largest island in Greece and the second largest (after Cyprus) in the Eastern Mediterranean. The island of Crete is a region of Greece, consisting of four prefectures:

- Chania
- Heraklion
- Lasithi
- Rethymno

Due to the hilly morphology of the territory and the insufficient road infrastructure, the 112 active olive mills in the Chania prefecture (535 in the whole island) are dispersed mainly on the north side of the region. The treated annually amount of olives in the prefecture is around 133.000 tn and the most used olive oil extracting process in the prefecture is the 3-phase centrifugal system.

In the local language this type of residue is called either depleted pomace or exhausted pomace. Cretan depleted pomace contains smashed olive kernel and dried olive pulp with humidity around 12% (no oil content)

In past years pomace oil refineries used to separate kernel/pit from the exhausted pomace. However through time, olive solid residues obtained greater interest as fuels and refineries stopped to separate pit from depleted pomace. Instead, they left it inside in order to keep the calorific value high.

The depleted pomace heating value (3500-4000 Kcal/ kg) and its price (approximately 0,05 Euros/kg); makes depleted pomace a very attractive option as a fuel in comparison to diesel. Although in Spain, the dried solid olive residues are used for power generation or for cogeneration of heat and power, this is not happening in Greece. Presently, in Greece these types of residues are used for space heating at small houses in some villages, at greenhouses for hot water production or through drying process at pomace oil refineries.

Dried solid olive residues have positive prospects for being used for power generation, heat and power cogeneration but only if there are subsidies due to the high cost of the investment.

Based on statistics provided by the Directorate of Rural Development, Regional Administration of Chania for the season 2007-2008, the total olive production forwarded for oil production as well as the total oil production extracted in the olive oil mills of the prefecture are listed in Table 2.

The estimated solid residues amount after the olive oil and pomace oil extraction in the prefecture of Chania is around 36.000 tn. Half of this amount is used during the drying process as fuel and as a result the available amount to be entered in the market is aprox. 18.000 tn. The table 2 below presents the treated olive amount and the estimated virgin pomace and depleted pomace derived from the processing methods.

**Table 2:** Treated olive amount and estimated solid residues

Chania prefecture, island of Crete, Greece			
2007-2008 (in kg/year)			
Treated olive amount	Estimated <u>virgin pomace</u> content after the 3-phase processing	Estimated <u>water</u> amount content in the virgin pomace	Estimated <u>depleted</u> (exhausted) <u>pomace</u> after the pomace oil extraction & drying
133.002.302	74.982.078	36.458.073	35.991.398

## 2. Analysis of the energy content of the available depleted pomace

In the Island, the majority of the olive oil mills is operating using the three-phase extraction technology (3.2% uses the traditional extraction system, 2.4% uses the 2-phase system & 94.4% uses the 3-phase system). Therefore, the solid residue, which contains olive pulp and pits, has relatively low water content and is forwarded to the olive pomace oil extraction plants for further processing.

In the Island of Crete, exist ten (10) operational olive pomace oil extraction plants and the overall pomace production is estimated at 100.000tn annually with small fluctuations from season to season. From this quantity, circa 50% is being consumed in the pomace oil refineries as heating fuel and the rest is sold to the local market at a relatively low price (50 €/t) as heating fuel. This product is the depleted (exhausted) pomace with no oil and with approximately 12% humidity.

The table 3 below presents the percentage production in each prefecture of the island of Crete.

**Table 3:** Percentage production of depleted pomace in each prefecture of the island of Crete

Prefectures in the island of Crete	Percentage of the annual production
Chania	29%
Rethymno	13%
Heraklion	57%
Lassithi	15%

By comparing energy cost for heating, depleted pomace has a significant advantage over heating diesel as the heat content per Euro is 15.454 kcal/€ for heating diesel (market price 0,60 €/L) and 81.020 kcal/€ for depleted pomace. Therefore, it is an opportunity for depleted pomace to become part of the solution for a non-fossil fuel energy system and ideally serve residential or/and industrial burner for heat production.

Given that the available depleted pomace to be sold as a fuel in the relevant market is around 18.000 tn per year (Table 4) the corresponding energy potential is around 290.000 GJ/year (lower heating value 16,00 MJ/kg).

#### Current Uses of depleted pomace in Crete

In Crete the use of the depleted pomace as fuel is well-known, since decades ago it has been used to heat the water needed through the olive oil extraction process. Other well-known usages are:

- space heating of houses
- space heating of greenhouses, or
- as fuel for drying purposes and/or for the production of hot water in various small-sized industries, local bakeries, wineries.
- In pomace oil refineries for drying of virgin pomace.

In years were the olive oil production is indicated rather high and the amounts of the corresponding residues are high, a percentage of this amount is being exported.

**Table 4:** Average pomace annual quantities in the Prefecture of Chania, Crete

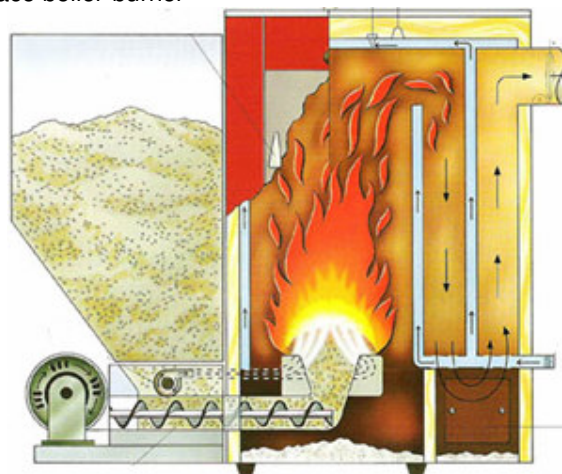
virgin pomace	74.982.078	kg/year
water content in virgin pomace	36.458.073	kg/year
depleted pomace	35.991.397	kg/year
depleted pomace lower heating value	16,00	MJ/kg
depleted pomace high heating value	18,10	MJ/kg
depleted pomace necessary to dry virgin pomace	17.995.699	kg/year
energy production by net depleted pomace	287.931.180	MJ/year
energy production by net depleted pomace	79.980.883	kWh/year

The energy value of the depleted pomace produced today in Crete is equivalent to aprox. 20% of the total energy consumption of the island.

The simplest way to exploit depleted pomace for energy production is by direct combustion. Combustion type boilers give off their heat to radiators in exactly the same way as e.g. a diesel-fired one. These boilers are mainly automatic; they are equipped with a silo containing depleted pomace. A screw feeder feeds the fuel simultaneously with the output demand of the dwelling. A typical example of depleted pomace boilers is shown in Picture 3.

Despite an often simple construction, most of the automatically fired boilers can achieve an efficiency of 80-90% and a CO emission of approximately 100 ppm. For some boilers, the figures are 92% and 20 ppm, respectively. An important condition for achieving these results is that the boiler efficiency during day-to-day operation is close to full load. For automatic boilers, it is of great importance that the boiler nominal output (at full load) does not exceed the maximum output demand in winter periods.

**Picture 3:** A typical pomace boiler-burner



In terms of environmental efficiency, the use of depleted pomace as fuel in comparison to diesel fuel has significant advantages such as:

1. Less CO<sub>2</sub> emissions, as the carbon released to the atmosphere can be considered as “green” carbon.
2. Less non regulated unburned hydrocarbons emissions, with positive effects to the air quality, especially at the urban areas.
3. Exploitation of a local renewable energy source.

General advantages over other energy sources for the use of depleted pomace as fuel are:

1. Decentralized and diversified energy supply system.
2. Storage stability and therefore, availability of fuel over the season.
3. Local development and additional income for rural enterprises.
4. Safer storage and transportation requirements.
5. High energy content.

### 3. Explanations of technical-managerial hypotheses

In order to assess and project future financial viability of an operation regarding biomass exploitation, it is critical to define a clear framework of working hypotheses. In the present study the applied hypotheses are listed in the following Table 5.

**Table 5:** Hypotheses and explanations

Hypothesis	Explanation
Feedstock to pomace ratio	- No pit extraction - Ratio adjusted to local technology (mostly 3-phase)
Olive extraction technology	- No major technology improvements
Local availability of olive pomace	- Based on statistics from season 2007-2008
Olive pomace residue	- Residue ratio resulted from existing experience in olive pomace plants
Market for produced pellets	- Wholesale market - Stable demand
Installation costs	- Investment cost 375 €/kg/h (linear scale)
Management & Maintenance costs	- Linear scale (0,075 €/kg)

The following technologies for the business plan were considered:

- Burner/Combustion
- Pelletization unit
- Cogeneration

Out of these three, co-generation is considered the most difficult to implement because it requires a more intensive and larger scale production plant which is difficult to implement given the annual pomace quantities. On the other hand, small scale biomass burners would be a more sustainable solution for the case of Chania region. The potential of making pellets out of pomace is also a viable alternative.

Therefore, in order to promote and support the energetic exploitation of solid residues from olive oil processing, in the present scenario is examined the direct collection of the depleted pomace from the olive pomace oil extraction mills and their proper transformation into combustible fuel.

#### 4. Direct Combustion for the needs of space heating in a Greenhouse

Although solar energy represents a significant factor in greenhouse heating, supplementary systems are a necessity for year round heat production. Coal, oil and gas are the most common forms of energy used for greenhouse heating. The choice of which fuel to use is based primarily on economics. Depleted pomace is also a viable alternative.

##### Central Heating.

Hot water or steam heating systems can be used to preheat irrigation water and prevent cold-water shock to plants. The heat is centrally provided by the boilers and transferred to the greenhouse environment either by pipes that are smooth or finned or by unit heat exchangers equipped with fans.

**Table 6:** Heat Transfer Coefficient for Greenhouse Construction Materials

<i>Material</i>	<i>Kcal/m<sup>2</sup></i>
Glass single layer	7,065
PE film, single layer	7,819

**Picture 4:** Greenhouse



Table 7 presents the Energy data for depleted pomace to be used in Greenhouse heating at Chania region and Table 8 & 9 the corresponding money saved and years of pay-back for the

replacement of an oil burner with a biomass burner. The area to be covered is around 266m<sup>3</sup> as shown in Picture 5.

**Table 7:** Energy data for depleted pomace to be used in Greenhouse heating

Depleted pomace burner power	150.000 kcal/hour
Hours of operation	800 hours/year
Annual burner heat output	120.000.000 kcal/year
Depleted pomace consumption	34.000 kg/year
Equivalent tonnes of diesel	12 TOE/year
Heat losses from the north greenhouse site	6.000.000 kcal
Total annual heat consumption	126.000.000 kcal
Equivalent electric energy	146.510 KWh
electric energy required for greenhouse equipment	8.195 KWh
Total greenhouse annual energy consumption	154.705 KWh
Percentage of electric energy consumption to the total annual greenhouse energy	5,3%
Average heat input requirements	7,74 Kcal/m <sup>2</sup>
Price of 180Kw burner boiler	27.000€

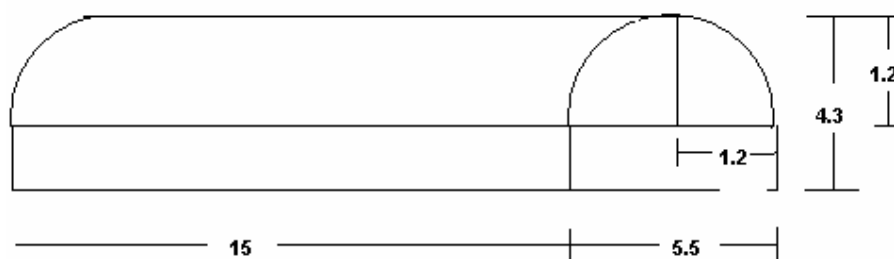
**Table 8:** Economic analysis

Equivalent tonnes of diesel	12 TOE/year	*0,60€/litre <sup>2</sup>	=8.280€
Depleted pomace consumption	34.000 kg/year	*50€/tn	=1.700€
Financial Gain			6.580€

**Table 9: Years of pay-back**

Price of 180Kw burner boiler	Money saved each year	Pay-back (simple method)
27.000€	6.580€	=4,1years

**Picture 5:** Greenhouse dimensions in meters



## 5. Pelletizing plant

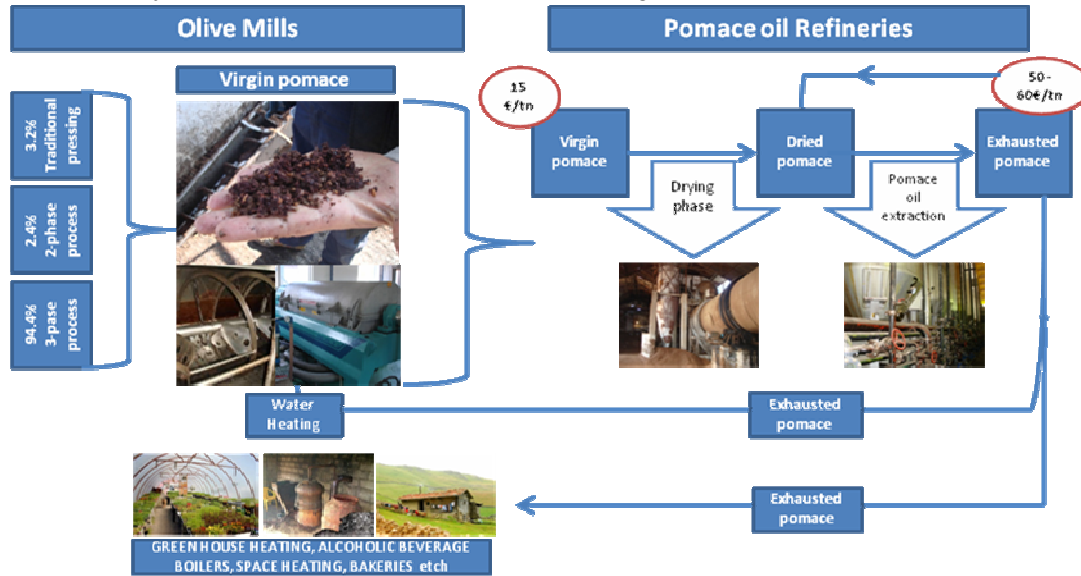
In the case of direct energy exploitation of pomace, these residues are collected and transported from pomace oil refineries to a central pelletizing facility, as bulk feedstock for pellets production. Further description is shown in the economic –financial assessment section.

### Analysis of the chain

Most of the Cretan olive growers (95-99%), give their crops to co-operatives which have their own olive mill, after harvesting the olives and pay the olive millers to extract the olive oil from their yearly crop. After the olive oil extracting process, the millers sell or exchange virgin pomace to the pomace oil refineries with depleted pomace. Depleted pomace in the island of Crete can be found at the price of 50€ per tonne while virgin pomace at 15€ per tonne. Pomace oil refineries extract the aprox. 2% content of pomace oil from the virgin pomace using a solvent, usually hexane (The price for pomace oil is 650€/tn). Finally after the drying phase and the subtraction of the solvent the resulted product named depleted pomace is ready to be sold as a fuel.

<sup>2</sup> One tonne of oil equals just over seven barrels or about 1,150 litres of oil

**Picture 6:** Analysis of the olive residues chain at Chania region



The main disadvantages of the final product form (Picture 8) (depleted pomace) are that:

- It can not be easily distributed over long distances
- It can not be stored for an extended period of time due to its chemical nature.
- The remained ash after the combustion is in higher quantities in contrast to other biomass fuel sources and needs to be removed in shorter periods of time.
- Some technical problems have been observed when combusted in small-size burners due to its chemical nature.

For this reason, it is mainly storage in bags (Picture 7) and sold to the local small-sized industries for direct combustion.

**Picture 7:** Storage of depleted pomace in bags



**Picture 8:** Depleted pomace in its natural form



To overcome in some extent the disadvantages arisen, the option of transforming depleted pomace into pellets (Picture 9) is suggested. In this way the quantities that are to be exported would be exploited now at local level. Greenhouses at the region which now use diesel or pellets made from wood residues for their heating needs, they could also now use pellets from depleted pomace.

**Picture 9:** Depleted pomace in pellets form



**Ownership structure**

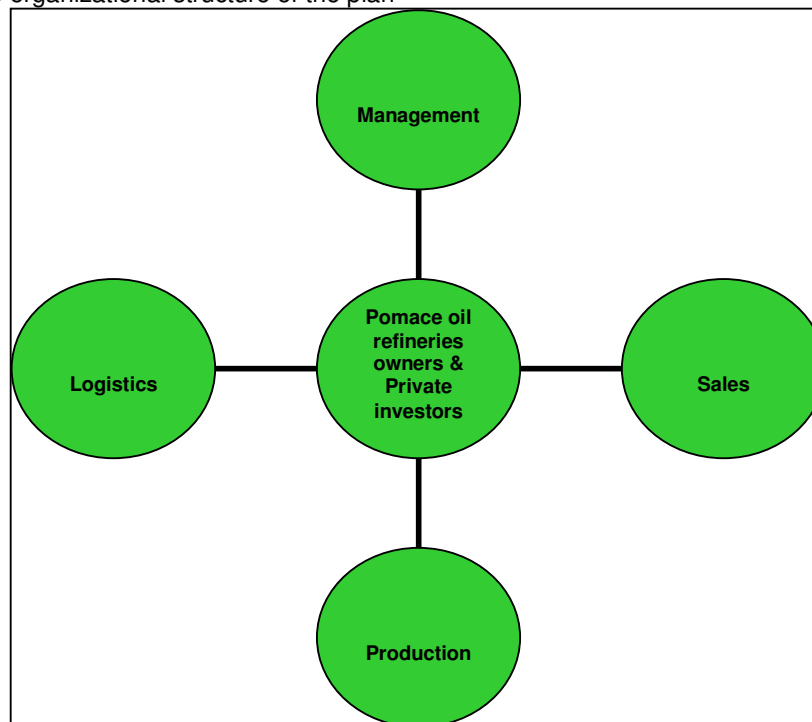
An indicative diagram of the organizational structure is shown in Graph 1.

To better promote and support the energetic exploitation of solid residues from olive oil processing, in the present scenario is examined the collection of the dried solid olive residues (*depleted pomace*) from the pomace oil refineries and their proper transformation into pellets.

In the case of pelletization, the produced solid residues which are collected and transported from olive oil extraction mills to pomace oil refineries are suggested to be forwarded to a pelletizing plant, as bulk feedstock for pellets production.

In order to mitigate the vulnerability of the venture regarding the acquisition of feedstock and to sustain the cooperation of the pomace oil refineries owners, the ownership structure of the business is containing a partnership between the feedstock providers and a private financing. It is strongly proposed to be developed a joint venture between local refinery owners and private investors, where feedstock acquisition would be ensured. This will create synergies and a win-win situation for the stakeholders and will reduce risk and sustain the business operational. An indicative radial diagram of the organizational structure is shown in Graph 1

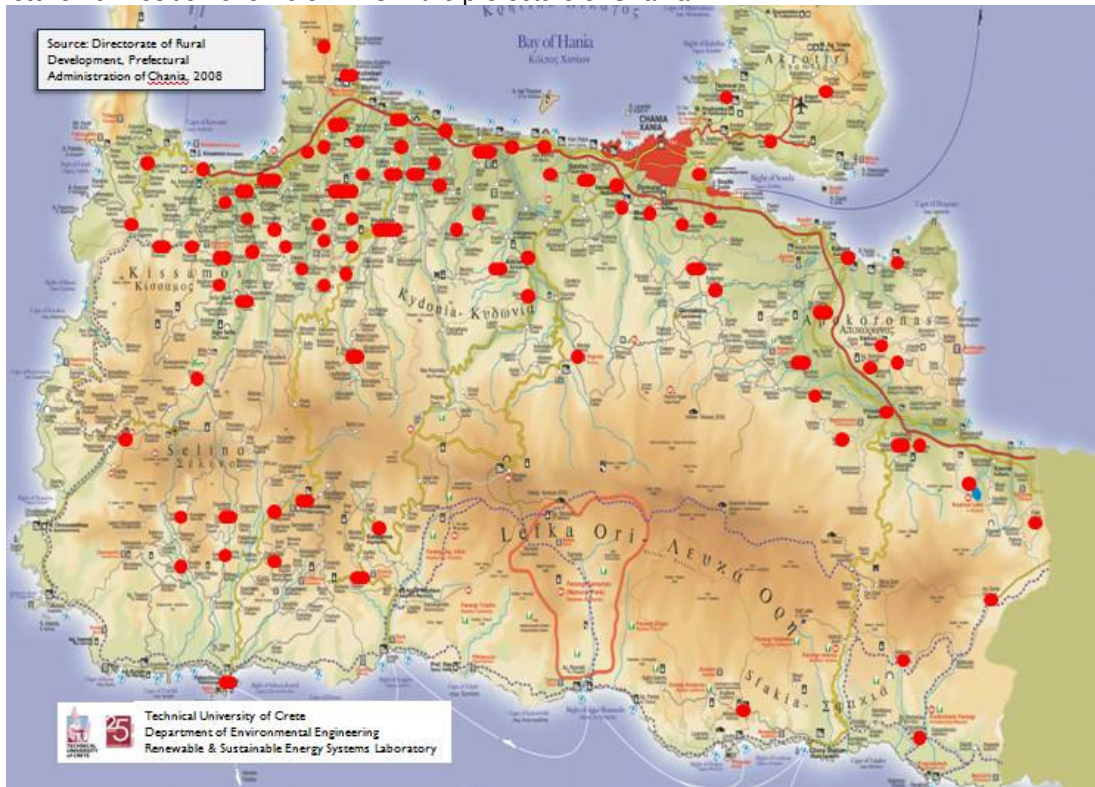
**Graph 1:** The organizational structure of the plan



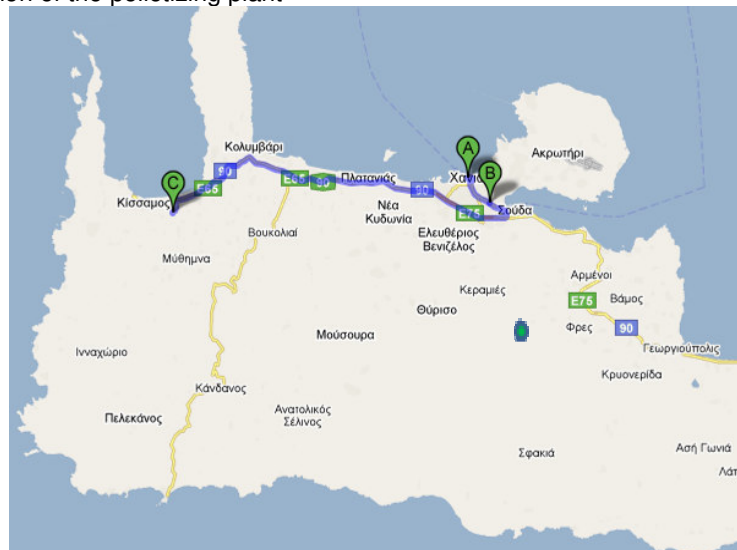
**Place and logistic aspects**

Picture 10, presents with the red spots the location of the olive mills in the prefecture of Chania and with the green spots the pomace refineries. As the majority of the olive mills and refineries are located at the north-western part of the region and too minimize the overall collection cost ranks as one of the most crucial issues regarding the feasibility of the project it is suggested that the pelletizing plant is constructed within this area.

**Picture 10:** Position of olive oil mills in the prefecture of Chania



**Picture 11:** Position of the pelletizing plant



Among the various possible locations for the installation of the plant, the wider area of Kolymbari at the north-west coast of Crete island was selected as the most suitable. The best location of the processing installation units considered to be somewhere between the pomace oil refineries A & B & C (Picture 11) with the biggest production of depleted pomace.

**Table 10:** Pomace Oil Refineries of Chania Prefecture and their distance from the pelletizing unit

Pomace Oil Refineries	Average Distance from the pelletizing unit (km)
Pontikakis	28
Giannoulis	28
Abea	28

### Economic-financial assessment

The proposed project scheme requires the installation of a drying unit for the further humidity reduction of the depleted pomace to reach the homogeneous humidity. In addition to this, a pelletizing unit able to process the total dried residue amount is required to be installed in a location close to the pomace oil refineries in order to minimize the transportation cost.

The drying phase of virgin pomace is taking place at the 3 pomace oil refineries of the region. For the pelletiser unit we need

- Land
- Building Construction (600m<sup>2</sup>)
- Equipment of production line
- Trucks
- Staff

**Table 111:** The Equipment of the production line is shown below

	<b>HAMMER MIL</b>	135.000€	70 KW
	<b>PELLETISER</b>	225.000€	10 KW
	<b>DRIER</b> (In case of non existence of pomace oil refineries)	600.000	120 kw
	<b>COOLING</b>	60.000€	10 KW
	<b>STORAGE</b>	165.000€	5 KW
	<b>ELECTRONIC CONTROL SYSTEM</b>	15.000€	5 KW

The total installation costs as well as other cost issues are presented in Table 12 as were resulted from the cost calculation tool provided by the ARE Lig agency.

The current energy market in the region of Chania is mostly based on electricity and fossil fuel consumption, which, due to the isolation from the mainland electricity network and the high

transportation cost for fossil fuels, has limited security, increased cost and it is unsustainable. Thus, energy supply cost in Crete is dependent on the cost of fossil fuels and increased compared to the price of energy in the Greek mainland. In order to evaluate and assess the economical feasibility of the project, when evaluating the market penetration and acceptance, special attention must be given due to the close relationship and bonds of local community to olive tree products. Financial evaluation results are presented in Table 13.

**Table 12:** Pellet Plant figures

pellettiser unit cost	375	€/kg/h
working days	300	dd/year
maintenance-management unit costs	0,075	€/kg
Virgin pomace available	17.995.699	kg/anno
plant size	4.999	kg/hr
plant cost investment	1.874.552	€
pellet price	0,17	€/kg
operational costs	0,075	€/kg
yearly production	17.995.699	kg/year
pellet production intermediate income	1.538.632	€/year
pomace transport cost	251.940	€/year
depleted pomace cost	899.785	€/year
pellet production income	386.908	€/year

**Table 13:** Investment payback period

year	disc. fact.	cash flow	net preset value
1	0,990099	232.145	-1.644.706
2	0,980296	232.145	-1.417.136
3	0,9705901	232.145	-1.191.818
4	0,9609803	232.145	-968.732
5	0,9514657	232.145	-747.855
6	0,9420452	232.145	-529.164
7	0,9327181	232.145	-312.639
8	0,9234832	232.145	-98.257
9	0,9143398	232.145	114.002

A hammer mill, a drier and a boiler are presented at Pictures 12, 13 and 14 correspondingly.

**Picture 12:** Hammer Mil



**Picture 13:** Drier



**Picture 14:** Boiler

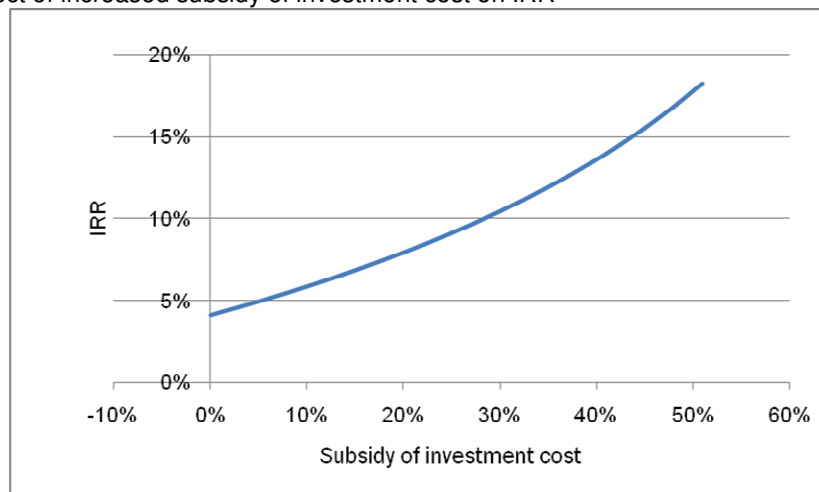


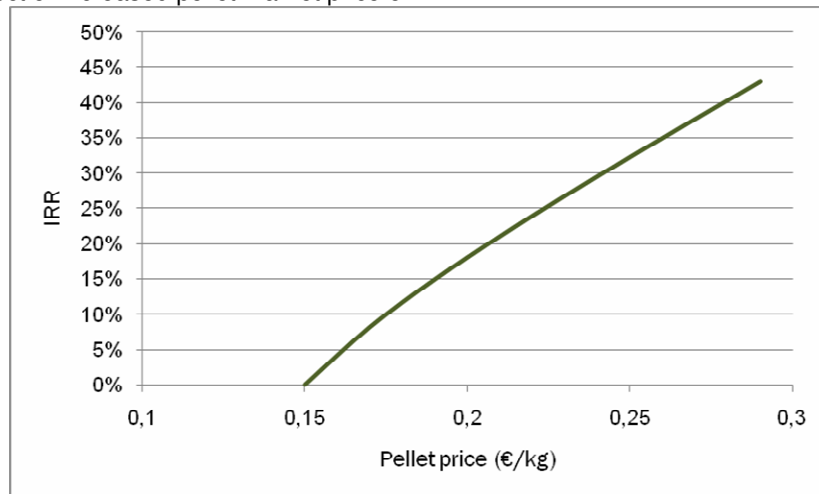
**Sensitivity analysis**

Due to the limited profitability of the proposed plan and in order to examine the risk of price fluctuations for pomace and pellet market, a sensitivity analysis is performed in order to assess the vulnerability of the project. On Graph 2 and Graph 3, are depicted the effect of increased subsidy of the investment cost and pellet price on the Internal Rate of Return (IRR) of the investment.

From the diagrams below, it is concluded that the viability and the profitability of the venture is strongly dependant on the examined parameters (pellet price and subsidy percentage). Therefore, it is crucial to define a market penetration strategy and to exploit subsidy opportunities beforehand in order to secure optimal financial efficiency of the investment.

**Graph 2:** Effect of increased subsidy of investment cost on IRR



**Graph 3:** Effect of increased pellet market price on IRR

### Conclusions and Recommendations

In general, any biomass investment opportunity has a number of operational parameters that are crucial for the future and the potential of the business. In this case, exploitation of olive pomace through pelletizing could be a potentially profitable. Prerequisites for a successful implementation of a pelletizing industry in the area of Chania or wider Crete are:

1. Stability in olive pomace price
2. Stable or increasing energy price of fuels, including pellets & diesel
3. Market development of olive pomace pellets

The recommendations, while are not definite, are meant to assist potential interested parties in taking over similar ventures. After the study, the following recommendations are suggested:

- Assess deeper the investment and the process costs for pelletizing
- Develop a concrete market plan and establish synergies with existing systems
- Evaluate the market potential, taking into consideration the quality issues related to the olive pomace feedstock
- Explain reasons why olive pomace energetic exploitation has not yet realized
- Examine scale economies by exploitation of olive pomace from all Cretan olive pomace plants
- Investigate potential alternative solutions to pelletizing (e.g. gasification)
- Examine the potential of missing depleted pomace for heating and cooling (through absorption chillers) and through solar technologies

## 6. Power generation or cogeneration of heat and power

Depleted pomace can be used for power generation or cogeneration of heat and power on Crete, since it presents many advantages, such as:

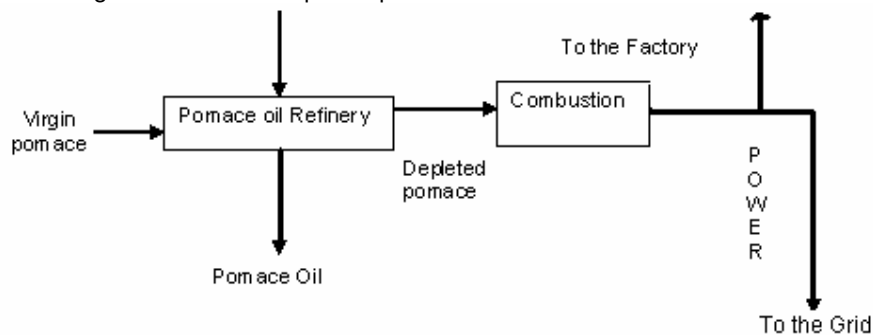
1. There is no need for harvesting of raw materials and transport of them because it is produced in the Pomace Oil refineries.
2. Its moisture content is very low and its heating value is high.
3. Its price is rather low in comparison with its heating value.
4. The combustion technology is well known. Since it is granular, either fixed bed reactors or fluidized bed reactors can be used.
5. The generated power can be consumed either inside the plant or can be sent to the grid.
6. The use of Biomass for power generation on Crete will reduce the CO<sub>2</sub> emissions on the island.
7. In the case that such a plant should be created, various other solid agricultural residues can be used with the depleted pomace as raw materials.
8. The creation of such a plant will help in the generation of power to and from small-decentralized plants instead of larger centralized power plants that exist today on Crete.
9. The sulphur content of depleted pomace is minimal.
10. The efficiency of small-sized combustion plants is very low. The depleted pomace processing plants operate seasonally. The produced heat from depleted pomace should be used at the

- time that cogeneration of the heat and power is obtained (during its operational period which is from November – April), or outside the plant for nearby heat-requiring operations.
11. Initially, the price of the Depleted pomace will rise, due to an initial local deficit of this Biomass source.

**Table 14:** Characteristics of a power plant consuming depleted pomace as a fuel on Crete

<b>NOMINAL POWER</b>	<b>3 MW</b>
Operating hours/ year	8000 hours/ year
Energy generation	24.000 MWh/ year
Plant efficiency	20%
Depleted pomace consumption	27.180 tn/ year
Heating Value of the Depleted pomace	3800 Kcal/ kg
Capital Cost of the plant	4,8 million Euros
Subsidies (40%)	1,92 million Euros
Cost of Depleted pomace / year	1.359.000 Euros/ year
Consumption of Depleted pomace in the plant	3,4 tn/ hour
CO <sub>2</sub> emissions which are avoided	29.137 tn/ year
Energy generation from the plant as % of total Energy Consumption on Crete	1,04%

**Picture 15:** Power generation from depleted pomace



The annual available quantity of 18.000 tn/year of depleted pomace in the prefecture of Chania is not sufficient by itself for the needs of the power plant (27.180 tn/year). Only if additional material may be made available from neighbouring areas, then the operation of such a plant can be made possible. In this case, transportation costs will have to be carefully considered. The 18.000 tn available at Chania would be sufficient for a 2MWe plant assuring all depleted pomace is used exclusively.

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