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Pellets Production from Olive Tree Byproducts and Residues: A case study in Crete – Greece

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Abstract

Wood pellet is a renewable solid fuel which finds broad applications mainly for heating buildings all over the world. Wood pellets constitute a non conventional fuel with neutral impacts to the greenhouse effect and they are produced from various agricultural and forest wastes, byproducts and residues. Olive trees are cultivated in the island of Crete – Greece as well as in many other Mediterranean countries producing large quantities of olive oil. Various byproducts and residues of the Olive trees like olive tree wood, olive Kernel wood and olive tree prunings are produced in large quantities and some of them are utilized currently for heat generation in Crete. These olive byproducts and residues have very good burning characteristics and they can be used for the production of wood pellets in Crete. Economic assessment of a pellets production plant in Crete proves that their production under various conditions is economically viable offering additional social and environmental benefits.

Keywords: biomass, Crete, olive Kernel wood, olive tree, olive tree prunings, pellets production.

1. Introduction

The necessity for mitigation of greenhouse effect results in the increasing use of various renewable energy sources including biomass as well as in smaller dependence on fossil fuels. Exploitation of local endogenous biomass resources for energy generation results in higher energy security and lower needs for oil and gas imports for many countries. In various Mediterranean countries olive trees are extensively cultivated and apart from the excellent quality of the produced olive oil various byproducts and residues from those trees are also co-produced. Due to the fact that they have very good burning characteristics and high calorific value they are currently used for heat production.

Because of the current economic crisis in Greece and the increasing energy poverty in the society there is a need of many households to shift from fossil fuels like heating oil and natural gas to cheaper fuels including biofuels. Since the demand for low price unconventional fuels is increasing the exploitation of various agricultural byproducts and residues is of primary importance.

Wood pellets market in Europe is growing and some countries have imposed quality standards for them. However in Greece although there are various local manufacturers of wood pellets, the legal framework for pellets quality specification does not exist.

Pellets can be used for heat generation in houses and in other buildings competing conventional fuels like heating oil, natural gas and electricity. The cost of pellets burning equipments like stoves, open fires or central heating systems is relative low. Agricultural and forest residues which are used as raw materials must have low moisture and ash content in order to produce good quality pellets. Pellets production process is not complicated and includes grinding and drying of the raw materials before pressing them to the required form and size.

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It is expected that in the foreseeable future wood pellets will have growing applications as an unconventional but attractive renewable fuel. Many reports, studies and research results have been published on pellets production and use.

A comparison of wood pellet production cost in Austrian and Swedish conditions has been presented by Thek and Obernberger, 2004. According to them production cost of wood pellets mainly depends on raw materials cost and their drying cost if needed. Other factors influencing the cost are plant utilization and raw materials availability. They found that the production cost of wood pellets in Austria in higher than in Sweden due to drying and raw materials costs.

A study of the obstacles and success factors of pellets production in forest industry in Sweden has been reported by Wolf et al, 2006. They suggested that an existing pellets market is a success factor for their production as well as the existence of the raw material nearby the production plant.

A study of agricultural pellets market in Greece has been presented by Karkania et al, 2012. They have reported that agro-residues constitute the biggest source of biomass in Greece without being exploited for energy generation. However since the pellets market in Greece is growing they should be used in the future for heat production.

An investigation of the economics of producing fuel pellets from biomass for the conditions of North America has been reported by Mani et al, 2006. They found that for plant capacity of 6 tons/h , pellets cost was 51 $/ton. Raw materials cost was the largest cost element, followed by personnel cost, drying cost and pelleting mill cost.

A study of the wood pellets production cost in Northeast Argentina has been reported by Uasuf et al, 2011. They found a relative low cost of 35 to 47 €/ton compared with other studies where the raw materials cost (sawmill residues) represented the main cost factor in the calculation of the final cost.

A report on the potential of biomass residues for energy production in the region Marvao in Portugal has been made by Fernandes et al, 2010. They concluded that the region has a potential over 10,000 tons /year of agricultural and forest residues which should be used for heat generation replacing fossil fuels.

A study on the agri-pellet production cost in Canada has been made from Sultana et al, 2010 . They have estimated that for annual production capacity from 70,000 to 150,000 tons the production cost varies from 170.89 $/ton to 122.17 $/ton.

An analysis on the Portuguese pellets market has been presented by Monteiro et al, 2012. They found that the reasons for the underdevelopment of the Portuguese pellets market, are mainly the lack of internal consumption and the shortage of raw materials mainly due to the competition of the available resources with the existing biomass power plants.

A study of the European wood pellet market and its prospects for 2020 has been implemented by Sikkema et al, 2011. According to them the final price of pellets for residential heating varied in various countries between 220 – 310 €/ton in the end of 2010.

2. Olive residues and byproducts in Crete-Greece

Crete has currently approx. 26 millions productive olive trees which produce various by products, wastes and residues like

a) Olive trees firewood
b) Olive Kernel wood
c) Olive tree prunings

Olive trees firewood is extensively used currently for heat production in wood stoves and wood open fires since it is considered as a very good fuel. Olive Kernel wood is a byproduct of olive Kernel oil producing industry after water removal and oil extraction of the olive mills paste and its annual production in Crete is approx. 110,000 tons . Its low price and its very good combustion characteristics makes it a very attractive fuel for heat generation in buildings, in industry and in agriculture. In tables 1 and 2 the chemical composition of olive kernel wood and olive husks is presented.

Table 1	
Chemical Analysis of olive Kernel wood	
Water content	6.30%
Ash	8.0 %
Organic matter	65.50 %
Sulphur	0.11 %
Total Carbon	45.30%
Hydrogen	5.17%
Nitrogen	1.33%
Oxygen	34.30%
Heating value	4,051 Kcal/kg, 16.96 MJ/kg
Residual oil	2.44 %
Residual hexane	≤ 10 mg/kg
Chlorine	0.69%

(Vourdoubas, 2008)

Table 2	
Chemical composition of Olive husks	
Ash	4.1 (w.t % of dry fuel)
Volatile matter	77.5 (w.t % of dry fuel)
Fixed carbon	18.4 (w.t % of dry fuel)
C	49.9 (w.t % of dry fuel with ash)
H	6.2 (w.t % of dry fuel with ash)
N	1.6 (w.t % of dry fuel with ash)
S	0.05 (w.t % dry fuel with ash)
Cl	0.2 (w.t % of dry fuel with ash)
O	42.0 (w.t % of dry fuel with ash)

(Demirbas, 2004)

Annual production of olive tree prunings in Crete is estimated at 1,550,000 tons. Usually the large size of them is separated and used for heat generation.However smaller sizes either are burnt in the fields, a practice which probably will be banned soon or they are grinded in situ and added into the soil to enrich it with organic matter. Since many olive tree groves are accessed with difficulty from transport vehicles a serious technical barrier exists for their collection and energy use.

In table 3 and 4 the chemical composition of olive tree prunings is presented.

Table 3	
Chemical composition of Olive tree prunings (% dry weight)	
Volatile matter	79.6
Fixed carbon	17.2
Ash	3.2
C	48.2
H	5.3
N	0.7
O	44.2
S	0.03
Gross calorific value	4,584 kcal/kg, 19.1 MJ/kg

(Vamvuka, 2010)

Table 4	
Chemical composition of Olive tree prunings	
Moisture (% w.b)	24.0
Fixed carbon	17.1 (% d.m.)
Volatile compounds	80.2 (% d.m.)
Ash	2.7 (% d.m.)
C	49.4 (% d.m.)
H	6.6 (% d.m.)
N	0.76 (% d.m.)
S	<0.05 (% d.m.)
C	0.03 (% d.m.)
Lower heating value	18.5 MJ/kg (d.m.)
K_2O	0.20 (% d.m.)
Na_2O	0.01 (% d.m.)

* w.b. = wet basis, d.m. = dry matter
(Martinez et.al., 2002)

1. European quality specifications of wood pellets

Various European countries have imposed official standards for wood pellets for non-industrial use. EU proposals published in the report CEN/TC 14961 exist also as suggestions but there are not yet official European quality specifications for wood pellets. In Table 5 the quality standards for wood pellets in Austria, Germany, Sweden and in CEN/TC 14961 are presented.

Table 5				
Various Quality Standards for wood Pellets in EU countries				
	Austria	Sweden (group 1)	Germany	CEN 14961 (for domestic heating use)
Bulk density		> 600 kg/m^3		-
Moisture content	<10 %	<10 %	<10 %	<10 %
Ash content	<0.5%	<0.7 %	<1.5 %	< 0.7 %
Calorific value	≥ 18 MJ/kg	≥ 16.9 MJ/kg	17.5-19.5 MJ/kg	≥ 4,042 kcal/kg 16.9 MJ/kg
Sulphur	≤ 0.04 %	≤ 0.08 %	< 0.04 %	≤ 0.05 %
Nitrogen	≤ 0.3 %	-	<0.3 %	< 0.3 %
Chlorine	≤ 0.02 %	≤ 0.03 %	≤ 0.03 %	<0.03 %
Arsenic			<0.8 mg/kg	
Cadmium			<0.5 mg/kg	
Chromium			<8 mg/kg	
Copper			<5 mg/kg	
Mercury			<0.05 mg/kg	
Lead			< 10 mg/kg	
Zinc			< 100 mg/kg	
Additives	<2 % , only natural			<2%

(www.bioenergynet.com)

2. Production technology of wood pellets

Production technology of wood pellets includes preprocessing, drying, grinding, conditioning, densification, cooling, screening and bagging. Depending on the type of biomass source some of these stages probably are not necessary.

After feeded to the plant the raw materials must be dried in most cases in order to decrease their moisture content to 12 % p.w. or slightly less. Since drying cost contributes significantly to the final cost of the pellets, it is important to minimize this cost or to avoid the drying stage if the initial moisture content of biomass is low. After drying, grinding of biomass is necessary in order to reduce its size to the desired levels. Next stage includes conditioning of the biomass where super heated steam at temperatures above 100 ^{0}C is used to soften the raw material.

Densification or pelletization follows and biomass enters in a extruder where it takes its final form. Since pressure is high at this stage lignin is softened and it helps the transformation of biomass to the final pellet form. During pelletization temperature rises to 90-95 ^{0}C due to high pressure and cooling is needed afterwards in order to solidify lignin and to increase the strength of the pellets.

5. Burning systems of wood pellets for heat production

Various burning systems like open fireplaces, stoves and domestic boilers are currently used for heat generation from pellets. The burning characteristics of pellets produced from various biomass sources have been studied (Gonzalez et al, 2004) in a domestic boiler.

They found that pellets produced from tomato residues and olive stones had excellent burning behaviour. Pellets produced from cardoon had high ash content (11.3 %) and low melting point so in this case continual removal of the ash from the fireplace was required.

Cost comparison of pellets which can be derived from olive Kernel wood with heating oil shows that heat from pellets costs 0.071 € /1,000 kcal delivered compared to 0.107 € /1,000 kcal delivered for heating oil. Therefore the cost of those pellets is only 66.36 % of the corresponding cost of heating oil.

6. Possibilities of pellets production from olive byproducts and residues in Crete-Greece

There is currently an increasing demand for wood pellets in households as a fuel substitute to heating oil in Crete and in Greece due to their relatively low price, compared with heating oil.

Also there is high availability of biomass resources like olive Kernel wood and olive tree prunings in Crete. Solid biomass is not used for power generation in Greece. Olive Kernel wood is currently used for heat but not for power generation.

Small size olive tree prunings are not used though for heat generation. However the chemical composition of the abovementioned biomass resources restricts their use for the production of high quality wood pellets.Since there are not quality specifications for wood pellets in Greece, olive Kernel wood and olive tree prunings can be used for the production of second quality pellets. The main drawback of these biomass resources is related with their high ash content, which is significantly higher than the existing upper limits in various EU countries.

The composition of olive Kernel wood in Sulphur and Nitrogen exceeds the upper limits as well. Olive tree prunings have better characteristics but their ash and Nitrogen content exceeds also the upper limits.
Between olive Kernel wood and olive tree prunings, the first has the drawback of relatively high price (0.08 €/kg) but low transportation cost from its production site in the olive Kernel oil producing plants to the pellets factory. The cost of Olive tree prunings is related with the cost of their collection and transport from the olive fields to their processing site.

The capacity of the pellets production plant is restricted from two adverse factors.

Firstly its capacity must be high enough to minimize production cost of pellets and secondly it must be low enough to avoid competition of the new use of olive Kernel wood with its other uses in Crete (as fuel for heat production) which could drive up its price.

To avoid biomass transport cost (which affects significantly the production cost) the pellets production plant must be located nearby the olive Kernel oil producing plants and nearby the olive fields. Currently there are nine olive Kernel oil producing plants operating in Crete.

Apart from heating buildings there is also a high demand of alternative fuels including biomass from large heat consumers in Crete like greenhouses and small size industries. This trend is increasing because of the current economic crisis in Greece and the high taxation and prices of heating oil.

Advantages of olive Kernel wood as a raw material for pellets production are

- It has low moisture content and the drying stage can be avoided.
- It is easily available and handleable in Crete
- It is easily transported to the processing site
- Due to its granular size it does not need grinding

Disadvantages of olive Kernel wood as a raw material for pellets production are

- Its high ash content restricts its use for first quality pellets.
- It has high Nitrogen and Sulphur content
- It has high purchasing cost
- Its use for pellets production could compete its other uses for heat generation in Crete.
- It has undesired odour due to fermentation of olive mills paste before its processing for the production of olive Kernel oil and olive kernel wood.

7. Estimation of capital and operating cost of a wood pellets production plant in Crete-Greece.

A preliminary estimation of the capital and operating cost of a wood pellets production plant in Crete-Greece has been made for two different capacities based on data presented by Thek et.al. , 2004, with reference to Austrian conditions.

a) Annual pellet production 2,253 tons (d.w.)/year
Investment cost (without dryer) 634,000 €
Working days per week 5
Shifts per day 1
Annual operating hours 1,877
Raw materials cost 80 €/ton
Processing cost 130 €/ton
Total production cost 210 €/ton
Selling price of pellets 230 €/ton
Ratio of raw materials cost to total production cost 38.10 %
Percentage of olive Kernel wood used annually to its total annual production in Crete 2.05 %
Annual profit 45,060 €

b) Annual pellet production 16,894 tons (d.w.) / year
Investment cost (without dryer) 1,167,000 €
Working hours per week 5
Shifts per day 3
Annual operating hours 5,631
Raw materials cost 80 € /ton
Processing cost 75 € /ton
Total production cost 155 € /ton
Selling price of pellets 230 € /ton
Ratio of raw materials cost to total production cost 51.61 %
Percentage of olive Kernel wood used annually to its total annual production in Crete 15.36 %
Annual profit 1,267,050 €

According to the estimations, higher plant capacity significantly decreases the total pellets production cost and increases the profit margin. However higher plant capacity will require higher quantities of olive kernel wood and it could probably increase its price since it will compete with other current uses of it. The ratio of raw materials cost to the total operating cost of pellets varies between 38.10% (capacity 2,253 tons/year) and 51.61% (capacity 16,894 tons/year) compared to 36.10% reported for the base case scenario in Austria from Thek et. al.,2004.

The low total production cost of pellets in Austria (90.7 € /ton) reported by the same authors is partly due to the higher plant capacity, 23,652 tons/year and the low raw materials cost, 32.7 € /ton. However it can be assumed that the raw materials for the pellets production plant will be both olive Kernel wood and olive tree prunings.

Analysis of pellets production cost in Sweden for large plant capacities of 79,716 tons/year results in total production cost of 62.4 € /ton (significantly lower than in Austria) and the raw materials cost of 31.28 € /ton represents 50.13% of their total production cost.

8. Profitability analysis of a pellets production plant using olive Kernel wood as raw material.

Estimation of net present values of the pellets production plant for a period of 15 years and an interest rate of 2% for the abovementioned two cases with capacities of 2,253 tons/year and 16,894 tons/year has been made. For each plant capacity seven scenarios have been investigated as follows.

S1 Base case scenario as shown previously
S2 10% increases in the price of raw materials, all other parameters remain the same
S3 20% increases in the price of raw materials, all other parameters remain the same.
S4 10% increases in pellets processing cost, all other parameters remain the same.
S5 20% increases in pellets processing cost, all other parameters remain the same.
S6 10% decreases in selling price of pellets, all other parameters remain the same.
S7 20% decreases in selling price of pellets, all other parameters remain the same.
Cost parameters for various scenarios are presented in table 6

Table 6
Various parameters of pellets production plant for seven different scenarios

	S1	S2	S3	S4	S5	S6	S7
Raw materials cost (€ /ton)	80	88	96	80	80	80	80
Processing cost (€ /ton)	130	130	130	143	156	130	130
Total production cost (€ /ton)	210	218	226	223	236	210	210
Selling price (€ /ton)	230	230	230	230	230	207	184

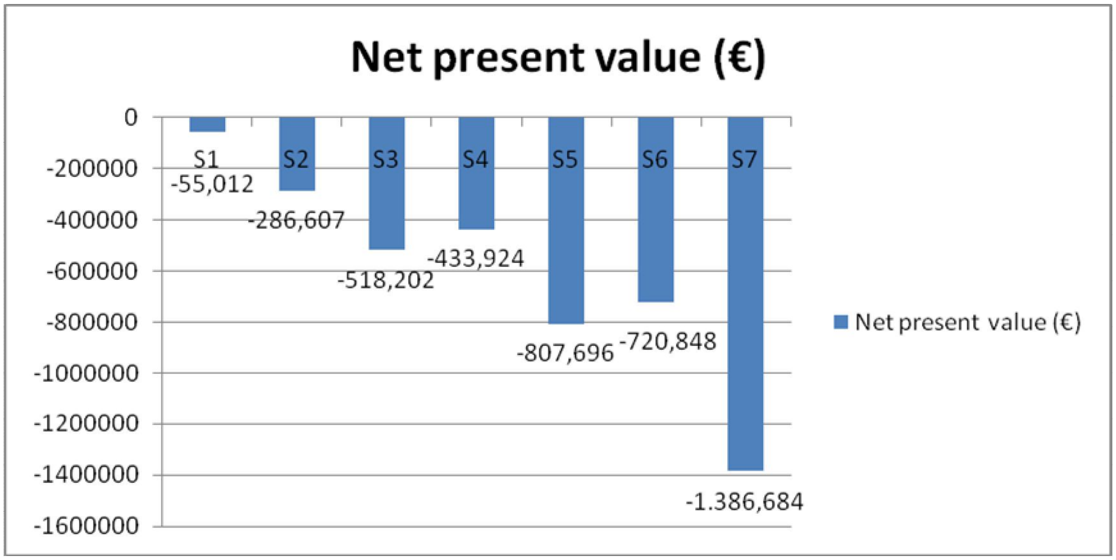
Economic results of the pellets production plant in Crete with capacity 2,253 tons/year are presented in table 7

Table 7
Economic results of the pellets production plant in Crete with capacity 2,253 tons/year

	S1	S2	S3	S4	S5	S6	S7
Annual revenues (€)	518,190	518,190	518,190	518,190	518,190	466,371	414,552
Annual costs (€)	473,130	491,154	509,178	502,419	531,708	473,130	473,130
Annual profit (€)	45,060	27,036	9,012	15,771	-13,518	-6,759	-58,578
Net present value (€)	-55,012	-286,607	-518,202	-433,924	-807,696	-720,848	-1,386,684

Net present value for the seven scenarios for 15 years operation and 2% interest rate of the pellets production plant with capacity 2,253 tons/year is presented in figure 1

Figure 1
Net present value for the pellets production plant in Crete with capacity 2,253 tons/year (seven different scenarios)



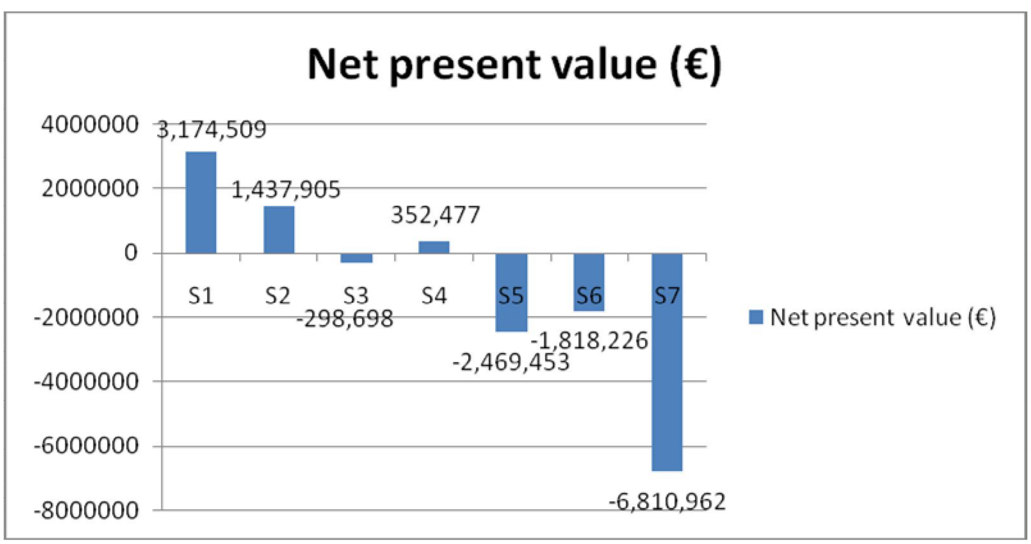
Economic results of the pellets production plant in Crete with capacity 16.894 tons/year are presented in table 8

Table 8
Economic results for the pellets production plant in Crete with capacity 16.894 tons/year

	S1	S2	S3	S4	S5	S6	S7
Annual revenues (€)	3,885,620	3,885,620	3,885,620	3,885,620	3,885,620	3,497.058	3,108,496
Annual costs (€)	3,547,740	3,682,892	3,818.044	3,767,362	3,986,984	3,547,740	3,547,740
Annual profit (€)	337,880	202,728	67,576	118,258	-101,364	-50,682	-439,244
Net present value (€)	3,174,509	1,437,905	-298,698	352,477	-2,469,453	-1,818,226	-6,810,962

Net present value for the seven scenarios for 15 years operation and 2% interest rate of the pellets production plant with capacity 16,894 tons/year in presented in figure 2

Figure 2
Net present value for the pellets production plant in Crete with capacity 16, 894 tons/year (seven different scenarios)



9. Environmental and social benefits

The use of olive residues and byproducts for pellets production results in various environmental and social benefits. Production of pellets in Crete – Greece will

a) Reduce greenhouse gases emissions in the country.
b) Reduce imports of fossil fuels mainly oil and natural gas.
c) Increase energy security
d) Decrease energy dependency

At the same time in local level it will

a) Increase investments in new plants.
b) Create local incomes and profits for the farmers and the local investors.
c) Increase employability and creation of new jobs.
d) Increase the production of heating systems using wood pellets as fuel.

10. Conclusions

There is currently an increasing interest in Greece and in Europe for wood pellets production which are mainly used for heat generation. However in most EU countries including Greece there are not quality specifications for them. In Crete with the cultivation of many millions olive trees, various residues and byproducts of them are produced.

Among various solid biomass sources olive Kernel wood has excellent burning characteristics and it is broadly used for heat production. Olive tree residues like small size tree prunings are not used for heat generation although they also have very good burning characteristics. The chemical composition of olive Kernel wood and olive tree prunings does not allow them to be used as raw materials for production of first quality wood pellets. They can though be used for production of second quality wood pellets suitable for heat generation in industrial boilers and in various buildings since their price is significantly lower than current heating oil prices.

Preliminary cost analysis of a pellets production plant in Crete using primarily olive Kernel wood has shown that it can be profitable under various conditions. A production plant with capacity 16,894 tons/year utilizing mainly olive Kernel wood with price 80 € /ton has satisfactory economic performance with pellets selling price at 230 € /ton. The high cost of olive kernel wood is the main cost factor in the total production cost of pellets, which is relatively high compared with the cost of pellets produced from other biomass sources. However pellets production plants with smaller capacities are not profitable in Crete mainly due to high prices of the olive Kernel wood and high operating costs in smaller capacity plants.

The profitability of this plant is negatively influenced by a lower selling price of wood pellets or a higher price of olive Kernel wood.

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