

MòRe

MARKET OF
OLIVE RESIDUES
FOR ENERGY

Booklet with guidelines for replication and a summary of the methodology envisaged for the setting up of structure for the management of olive residues for energy purposes.

Project: M.O.R.E. – Market of Olive Residues for Energy

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These guidelines aim at delivering helpful support in developing a structure for the energy exploitation of the solid olive residues (olive pomace). It is thus contributing to fill the observed gaps on the energy market of the olive pomace.

Furthermore, these guidelines focus on common accepted practices for the development of an olive pomace-to-energy plant. It thereby highlights important questions and criteria a product developer/investor should ask himself / herself when developing an energy pomace plant.

An approach, on how to quantify related energy-environmental and economic benefits generated by the olive-waste-to-energy development scenario, is described.

In a simplified concept an olive pomace-to-energy plant is placed in a “stress field” consisting of the olive growers, olive millers and refineries (see Figure 1).

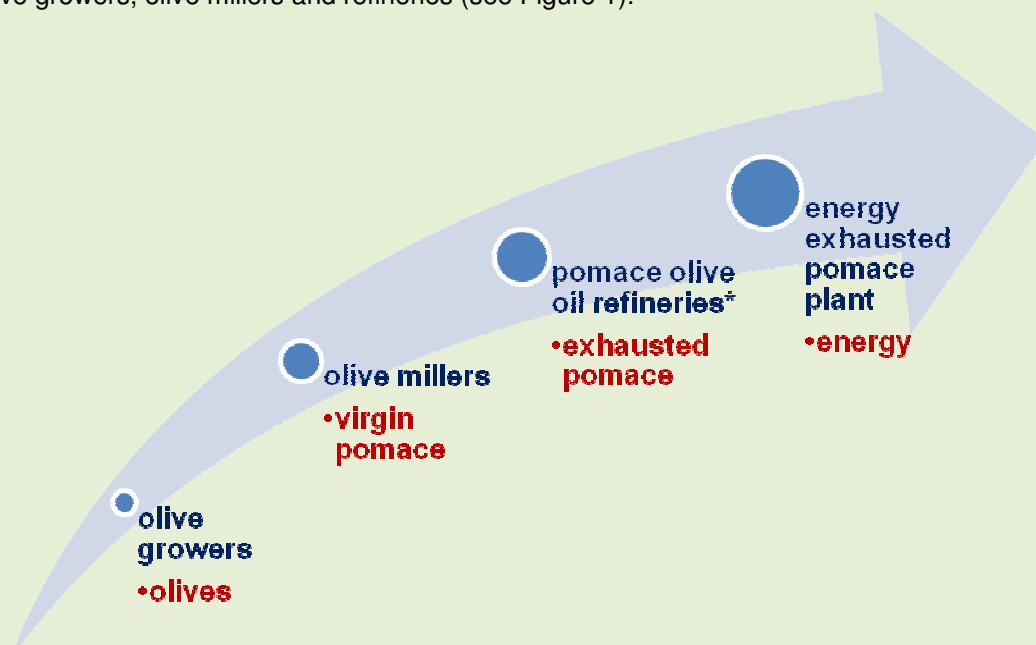


Figure 1: “Stress Field” of an olive pomace-to-energy plant development

Strategic project development therefore deals with questions referring to these elements:

- Which are the total pomace amounts to be exploited?
- How pomace oil refineries can further exploit the exhausted pomace for energy purposes?
- Which kinds of energy related solutions are attractive to the refineries?
- Which are the energy-environmental and economic benefits?
- Which are the strengths, weakness, opportunities, threats of the project development?
- Which kind of intermediate inputs are needed to facilitate the management the pomace residues?

Starting from the above “generic questions” the strategic **guidelines are structured as follows:**

- | |
|--|
| 1. As a first step an approach is described in order to estimate the future quantities of exhausted pomace through linear regression analysis (step 1). |
| 2. Next, an analysis of the possible solutions is demonstrated together with a SWOT |

analysis of the project (step 2).

3. At step 3 a business plan is implemented

The implementation of an energy pomace plant involves providers of Energy Efficiency Services (EES), but also providers of partial services connected to EES. These may come from different branches and backgrounds, such as:

- Energy utilities;
- Energy engineers / civil engineers;
- Technology suppliers;
- Installers;
- Facility managers;
- Financing institutions;

The “**value chain**” reflects the implementation of measures related to Energy Utilization:

Figure 2: Value chain

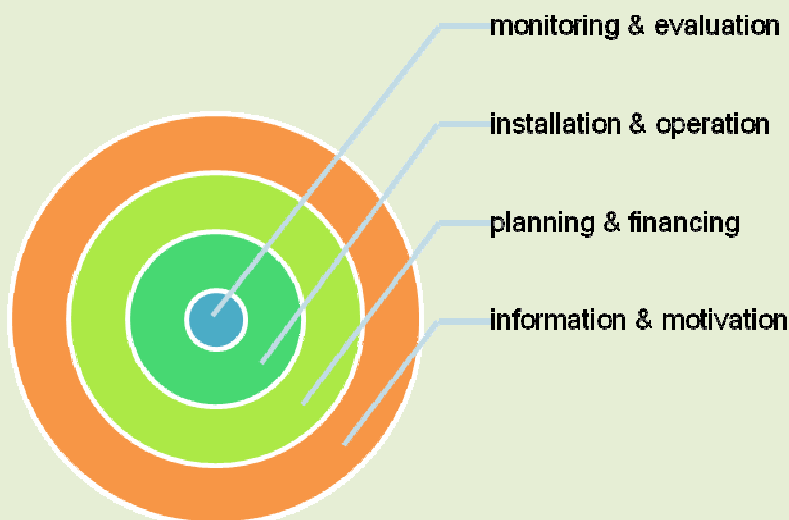


Figure 2 gives an overview over the basic phases for the implementation process of an olive-waste-to-energy development scenario. Table 1 shows a detailed structure of the single elements of the value chain.

Table 1: Detailed value chain

• Information & motivation	Shareholders, Key actors awareness, Dissemination of general information on energy exploitation of olive residues
• Planning & financing	Definition of the goals, detailed planning of the investment, preparation of the business plan, support in the application for subsidies, support in concluding a loan contract with a bank.
• installation & operation	Construction work, optimization of the operation, training of the users/staff
• monitoring & evaluation	Construction supervision, monitoring and controlling of cost, quality assurance

Step 1

The first step is focused on the study of the available raw material (pomace) in order to evaluate the energy potential. The projection of the future available sources is considered necessary for the assurance of the investment sustainability.

Linear regression models can be used to fit a predictive model to an observed data set of Y and X values. After developing such a model, if an additional value of X is then given without its accompanying value of Y, the fitted model can be used to make a prediction of the value of Y (source: wikipedia).

Example:

Having collected the available data of the exhausted pomace production of the last 10 years (table 1) we are able to forecast the production of the next 10 years (table 2), assuming that all the external factors that may affect the yearly production have the same behaviour with the last examined period.

Table 2: Estimated Olive solid pomace residues produced between the years 1994-2006 in the region of Chania, island of Crete, Greece (calculated from quantities of olives in mills)

(tn)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
exhausted pomace	28.379	29.762	39.512	36.561	38.945	40.945	36.364	35.198	36.016	35.999	32.690	38.088	37.649

Table 3: Forecast of the virgin and exhausted pomace production for the years 2007-2019 in the region of Chania, island of Crete, Greece

(tn)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
exhausted pomace	38.017	38.331	38.645	38.958	39.272	39.586	39.900	40.214	40.528	40.841	41.155	41.469	41.783

Graph 1: Diagram for projected exhausted pomace production in the region of Chania, island of Crete, Greece (t: time in years)

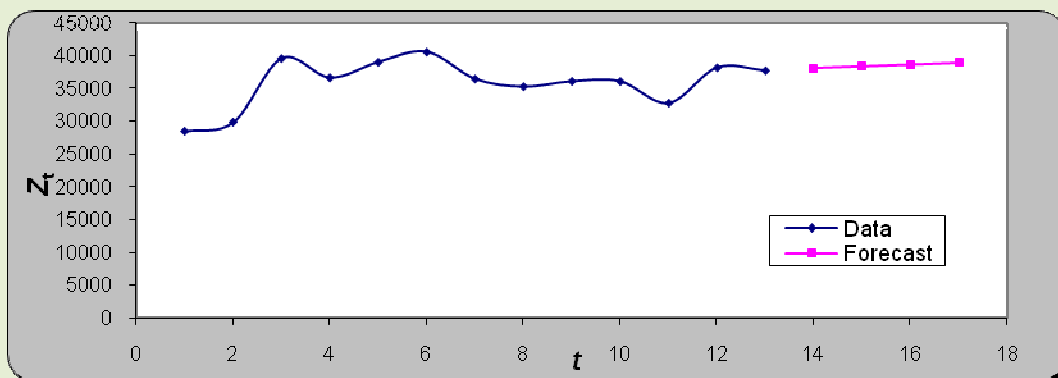


Table 4: Regression Statistics model for the exhausted pomace production in the region of Chania, island of Crete, Greece

Regression Statistics	
r^2	0,1143
MSE	12634615
Slope	313,8516
Intercept	33622,88

Having collected the data regarding the available current raw material and estimated the future quantities, the energy content of the exhausted pomace is calculated approx. 3.500-4.000 kcal/kg, (16 MJ/kg, 4,4 kWh/kg).

The tables below present **the equal energy content of the projected exhausted pomace production.**

Comparing the energy content of fossil fuels to exhausted pomace

Table 5: Equivalent energy content in Toe, "Handbook of Mechanical Engineering"

1tn exhausted pomace	"="	0,375 toe
1tn Natural Gas	"="	1,3865 toe
1tn Heating Oil	"="	1 toe
1tn Coal	"="	0,3328 to max of 0,8319 toe

For the projected amounts of the exhausted pomace (in toe), the equivalent quantities of natural gas, heating oil and coal (in tonnes) are given below.

Table 6: Energy content of exhausted pomace (in toe)

(toe)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
exhausted pomace	14.256	14.374	14.492	14.609	14.727	14.845	14.962	15.080	15.198	15.316	15.433	15.551	15.669

Table 7: Fossil fuel quantities corresponding to the energy content of exhausted pomace (in tonnes)

(tn)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
exhausted pomace	38.017	38.331	38.645	38.958	39.272	39.586	39.900	40.214	40.528	40.841	41.155	41.469	41.783
Natural Gas	10.282	10.367	10.452	10.537	10.622	10.707	10.792	10.876	10.961	11.046	11.131	11.216	11.301
Heating Oil	14.256	14.374	14.492	14.609	14.727	14.845	14.962	15.080	15.198	15.316	15.433	15.551	15.669
Coal	17.137	17.279	17.420	17.561	17.703	17.844	17.986	18.127	18.269	18.410	18.552	18.693	18.835

The corresponding **GHG Emissions resulting from combustion** are given to the following table

Table 8: Corresponding GHG Emissions resulting from combustion of different fuels (COM(2008) 781)

Energy source		Lifecycle GHG emissions tCO ₂ (eq)/toe
Fossil fuels	Natural gas	3.2
	Heating oil	4.1
	Coal	6.1
Biomass	Pellets	0.7

The corresponding **GHG Emissions to production of net electrical energy** from different fuels are shown below.

Table 9: Corresponding GHG Emissions to production of net electrical energy from different fuels

Energy source	Power generation technology		Lifecycle GHG emissions
			kg CO ₂ (eq)/MWh
Natural gas	Open Cycle Gas Turbine (GT)	-	640
	Combined Cycle Gas Turbine (CCGT)	-	420
		CCS	145
Oil	Internal Combustion Diesel Engine	-	690
	Combined Cycle Oil-fired Turbine (CC)	-	585
Coal	Pulverised Coal Combustion (PCC)	-	820
		CCS	270
	Circulating Fluidised Bed Combustion (CFBC)	-	960
	Integrated Gasification Combined Cycle (IGCC)	-	855
		CCS	270
Biomass	Solid biomass	-	21 ÷ 42

Since exhausted pomace is a biomass source it is clearly evident that its use is a far friendlier source of CO₂ emissions when it replaces fossil fuels for heating purposes.

Exhausted pomace can be used as a fuel source in free form or transformed into pellets. Up to now, it is mainly used in free form in local applications. However, there is technology readily available to transform it into pellet form and by that, extend its use to other locations and further applications.

The potential of generating electricity from pomace **in the region of Chania**, in the island of Crete, Greece is considered not feasible presently, due to the limited quantities and their current use as heating source.

Having estimated the future quantities and the energy content of the exhausted pomace, we can proceed to the next step regarding energy use.

Step 2

In general there are two approaches to exploit energetically the exhausted pomace:

- Direct combustion at biomass burners for the production of space heating or hot water. The simplest way to exploit 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 pomace.
- Combustion in a biomass plant for the production of electricity and/or district heating (CHP). Co-generation is considered the most difficult to implement method because it requires a more intensive and larger scale production plant. For the operation of a biomass plant, minimum quantities of the energy source are needed to ensure the sustainability of the plant. On the other hand, small scale biomass burners would be a more sustainable solution for the case of Chania region given the annual pomace quantities. The potential of making pellets out of pomace is also a viable alternative.

Developing a SWOT analysis

SWOT Analysis is the Key Component of Strategic Development. It can prompt actions and responses

Internal	External
Build on strengths	Exploit opportunities
Surpass weaknesses	Avoid threats

For example, in the particular case of pomace residue the following characteristics can be specified.

Potential Strengths:

- Olive pomace can be considered as a Renewable Energy Source (RES) so it can be subsumed in the framework for the exploitation of RES.
- Dry pomace has high enough heating value.
- It's a relatively inexpensive energy source.
- It's not fully exploited as an energy source.
- A stable olive residue to energy supply chain.
- The technology to use is known.
- Almost zero CO₂ emissions during life cycle.
- Pomace can be safely transported.
- Pomace can be used as a natural fertilizer.

Potential Weaknesses:

- High fragmentation/individualism amongst millers (difficulties in the creation of a supply chain)
- Small unconsolidated olive mills units
- Regional territory morphology which makes transport very expensive
- Seasonality of pomace and different quantities each year
- Limited availability of updated figures on quantity and location of pomace
- Unfavourable national normative framework on waste, by-products.
- Large investment cost.

Potential Opportunities

- Raising costs for fossil fuels
- Renewable energy generation
- New additional revenues for olive millers
- Presence of an interesting thermal energy demand (greenhouses) exactly where residues are located
- Presence of some utility companies interested in investing for a plant
- Potential CO₂ reductions
- Current EU legislations favours & subsidizes RES use

Potential Threats

- Lack of government support
- Air pollution deriving from pomace pellet combustion
- Change of consumer behaviour towards less expensive substitutes and products
- Unfavourable weather conditions.
- Lack of connection in the biomass sector.

Transforming SWOT analysis into actions

A framework by which SWOT issues can be developed into actions

1. Product (what do we want to exploit?)
2. Process (how we plan to do that?)
3. Customer (who will be interested?)
4. Distribution chain (how does it reach them?)
5. Finance (what are the prices, costs, investments, profits ?)
6. Administration (and how do we manage all this?)

Action 1**Product (what do we want to exploit?)**

The product in question is dry pomace (with or without pit and humidity of no more than 8%) derived from olive pressing. Dry Pomace can be used for combustion into a boiler to generate heat and/or electricity. Dry pomace has high enough heating value and it's relatively inexpensive and through unstable trend of petrol prices and the fact that pomace is not fully exploited it could be used as an inexpensive energy source. Current EU and national legislation supports and provides incentives for the use of biomass as fuel. Dry pomace can also be used as heat source especially if transformed into pellets. Applications include indoor space heating, swimming pool heating and electricity production. Moreover, olive tree prunings are also suitable as heating source in the form of pellets.

Action 2**Process (how we plan to do that?)**

The process of heating using dry pomace or pellets is rather simple and the technology is readily available. For dry pomace production, a pomace oil refinery is needed and in some cases these refineries are quite far from the mills. Accumulation (stocking) of pomace is usually an unstable process due to weather conditions, geographical diversities and unwillingness/unawareness of olive growers to use it as an energy source. In cases where collection of dry pomace/pits is accomplished, good examples of applications have been performed (for home/commercial space heating, electric power generation etc). Transportation issues need to be resolved in some cases due to remote distances between raw material and location of its use. The legal framework is also often a key issue as can simplify the use of solid residues for energy.

Action 3**Customer (who will be interested?)**

Potential users/customers could be home owners, commercial establishments (hotels, spas, etc.) industrial installations, public facilities (hospitals, schools, public swimming pools etc.) as well as power plants.

Action 4**Distribution chain (how does it reach them?)**

In order to assure a smooth and continuous flow between olive millers and final customers' collection, transportation and technology issues (biomass boilers, pelletizers, etc.) must be resolved. Contract agreements between chain actors will be needed. Technology providers are also necessary. Extensive dissemination efforts must be directed to the potential users in order to stir the market and attract customers

Action5**Finance (what are the prices, costs, investments, profits?)**

Calculations are necessary to compare the costs of using pits or pomace pellets (together with the acquisition of proper boilers) with the costs of other conventional fuels (diesel, natural gas etc). The heating values of the energy sources used must also be taken into account. For some applications (power plant uses for electrical energy generation or distance heating) a business plan should be developed.

Action 6**Administration (and how do we manage all this?)**

To obtain results, all key actors involved in the distribution chain must be clearly defined and well connected. The use of pits and pellets from olive residues may supplement similar biomass raw materials resulting from agricultural residues or even urban waste. This will be useful particularly in regions with other biomass sources and unstable olive solid residues. Companies involved in the pelletization business could undertake administrative role between the partners involved (olive mills-

refineries-customers).

Step 3

The total **installation costs** as well as **other cost issues**, transportation cost, staff cost, operation cost etc should be calculated. The next more important value to be calculated is the required period of time for the **return on the investment**.

In order to examine the risk of price fluctuations for pomace, a **sensitivity analysis** has to be performed assessing factors which will influence the viability of the project.

The viability and the profitability of the venture is usually dependant on parameters such as subsidy percentage and the available quantities of pomace. 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.

Example:

Table 10: Characteristics of a power plant consuming exhausted pomace as fuel in Crete

NOMINAL POWER	3 MW
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 ₂ emissions which are avoided	29.137 tn/ year
Energy generation from the plant as % of total Energy Consumption on Crete	1,04%

Figure 3: Power generation from depleted pomace

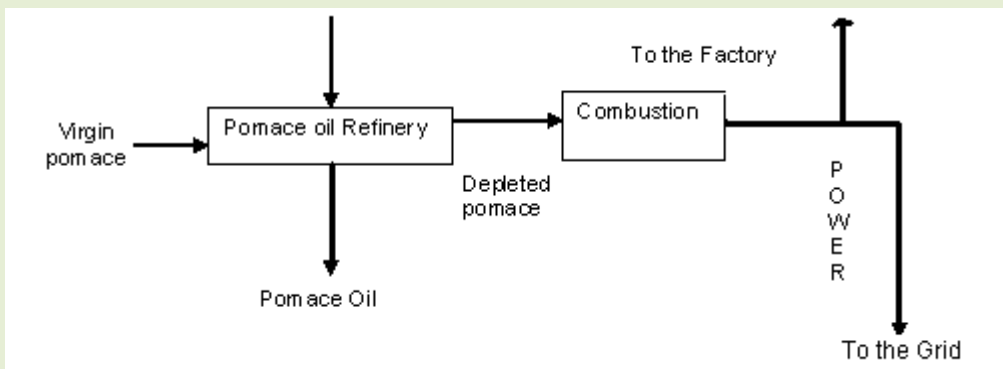


Table 11: Characteristics of a **Pellet Plant** using exhausted pomace as a raw material

pellettiser unit cost	375	€/(kg/h)
Operating days/ year	300	dd/year
maintenance-management unit costs	0,075	€/kg
Virgin pomace available	17.995.699	kg/anno
plant size	5.000	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 12: Investment payback period for the construction of a Pellet Plant (no subsidy)

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

In case of subsidies a substantial decrease to the payback period will be obtained.