SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

SWIM-H2020 – Regional Training
Waste to Energy Exploitation of Olive Mills Waste Streams

Presented by:

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SWIM and Horizon 2020

05/12/2017, Athens, Greece

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Presentation Structure

1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

3. Pilot station for OMSW pelleting

4. Q+A

1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

European Directive 2009/28 on the promotion of the use of energy from renewable sources

- The **EU's Renewable energy directive** sets a binding target of **20% final energy consumption from renewable sources by 2020**. To achieve this, EU countries have committed to reaching **their own national renewables targets** ranging from 10% in Malta to 49% in Sweden. They are also each required to have at least 10% of their transport fuels come from renewable sources by 2020.

- All EU countries have adopted **national renewable energy action plans** showing what actions they intend to take to meet their renewables targets. These plans include sectorial targets for electricity, heating and cooling, and transport; planned policy measures; the different mix of renewables technologies they expect to employ; and the planned use of cooperation mechanisms.

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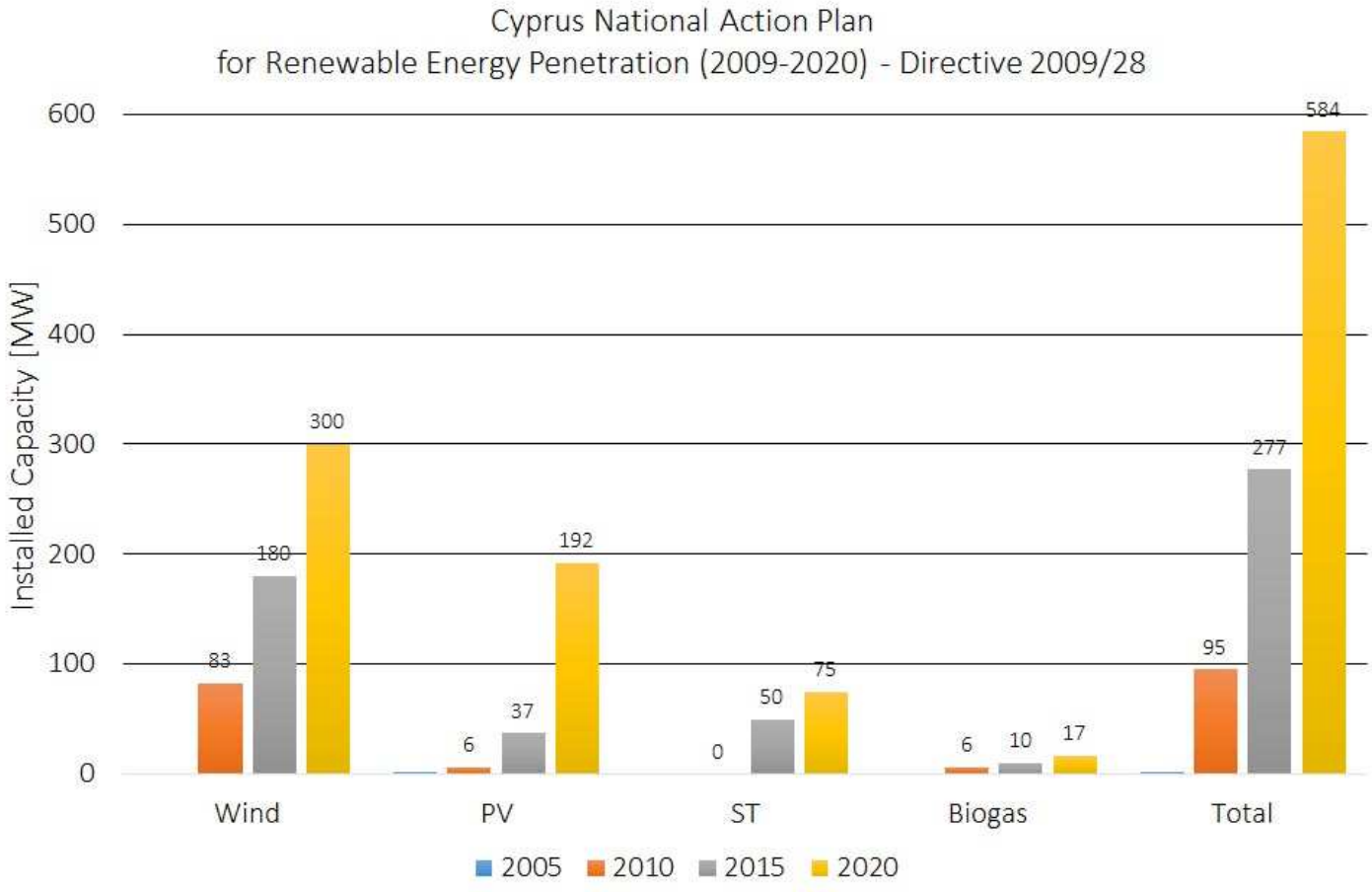
1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

European Directive 2009/28 on the promotion of the use of energy from renewable sources – National Action Plans

Link

1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

European Directive 2009/28 on the promotion of the use of energy from renewable sources – Cyprus National Action Plan



1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

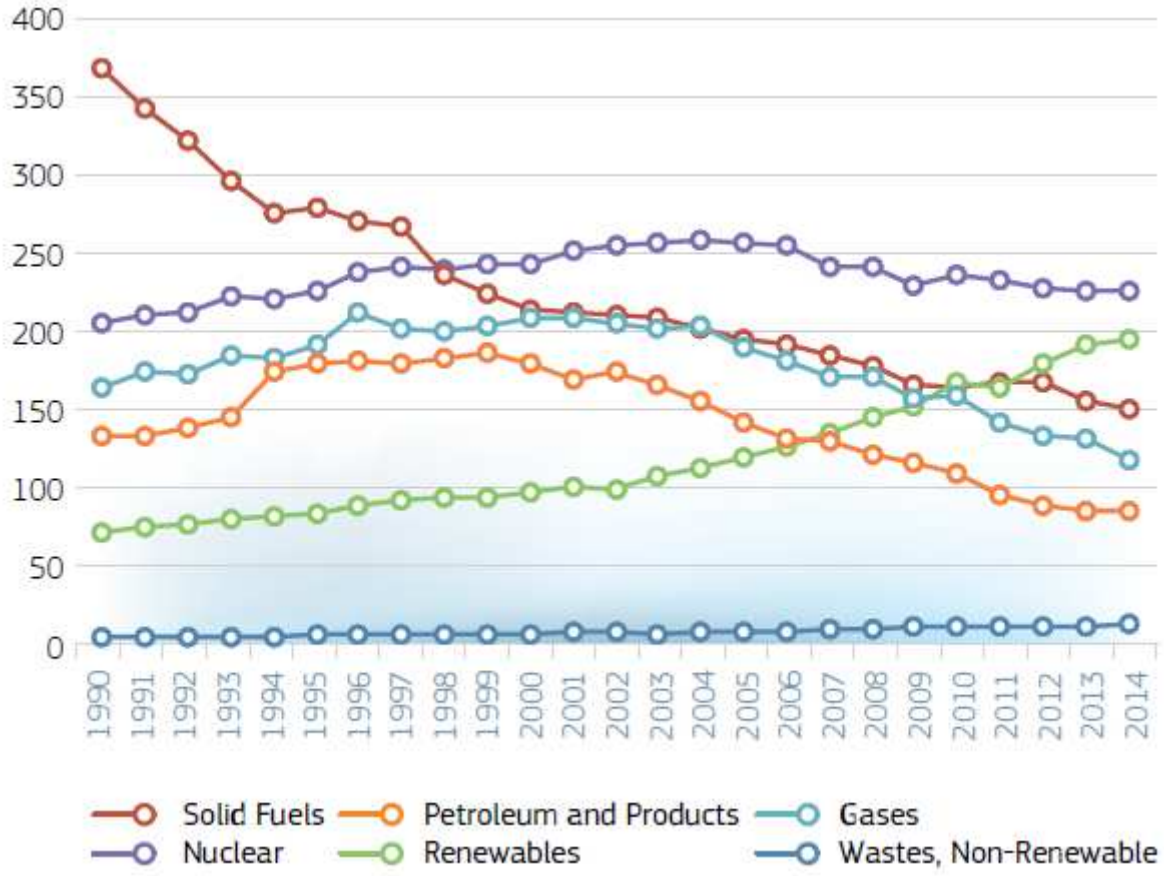
Renewable Energy Technology Units connected to the Grid – Cyprus September 2017

	Wind	PV	ST	Biogas	Total
Units	6	1931	0	14	1951
Capacity [MW]	157.5	70.6	0	9.7	237.8
Production [MWh]	1353121	413301	0	304045	2070467

Link

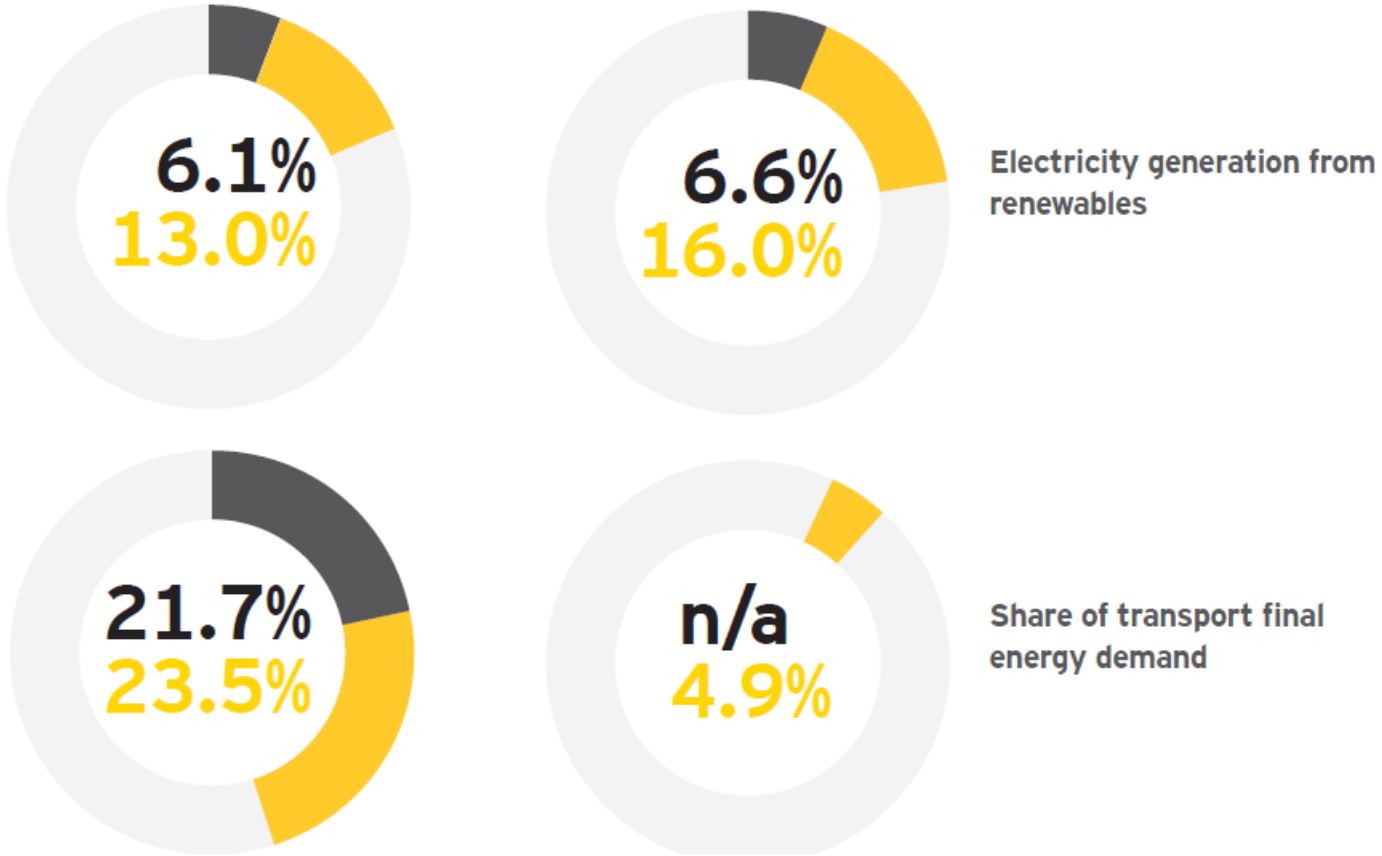
1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

European Directive 2009/28 on the promotion of the use of energy from renewable sources – EU Production by Fuel 1990-2014



1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

Energy Dynamics in Cyprus



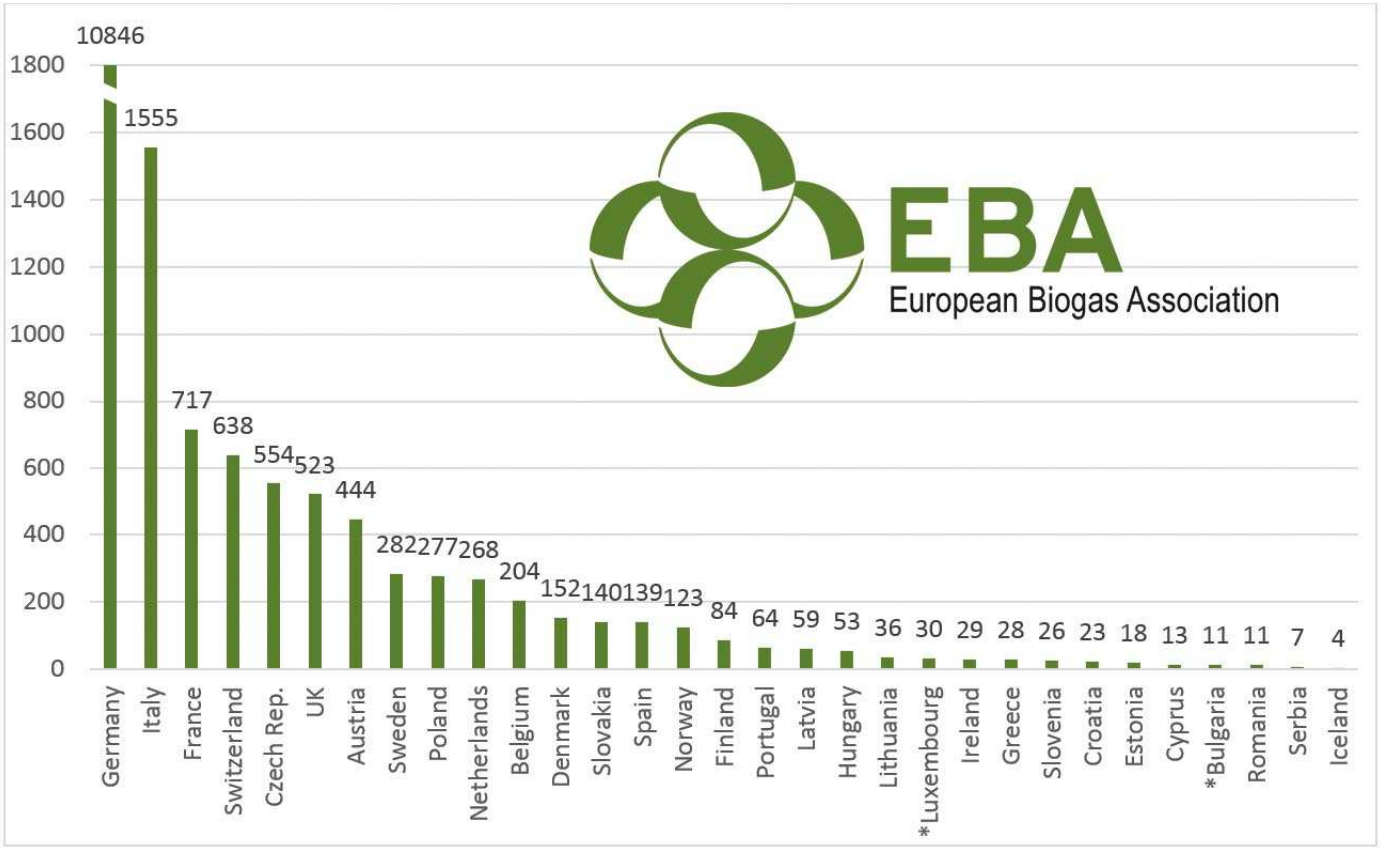
1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

Definition of Renewable Energy

- ‘Energy from renewable sources’ means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, **biomass, landfill gas, sewage treatment plant gas and biogases**;
- ‘Biomass’ means the biodegradable fraction of products, waste and residues from biological origin **from agriculture (including vegetal and animal substances)**, forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste;

1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

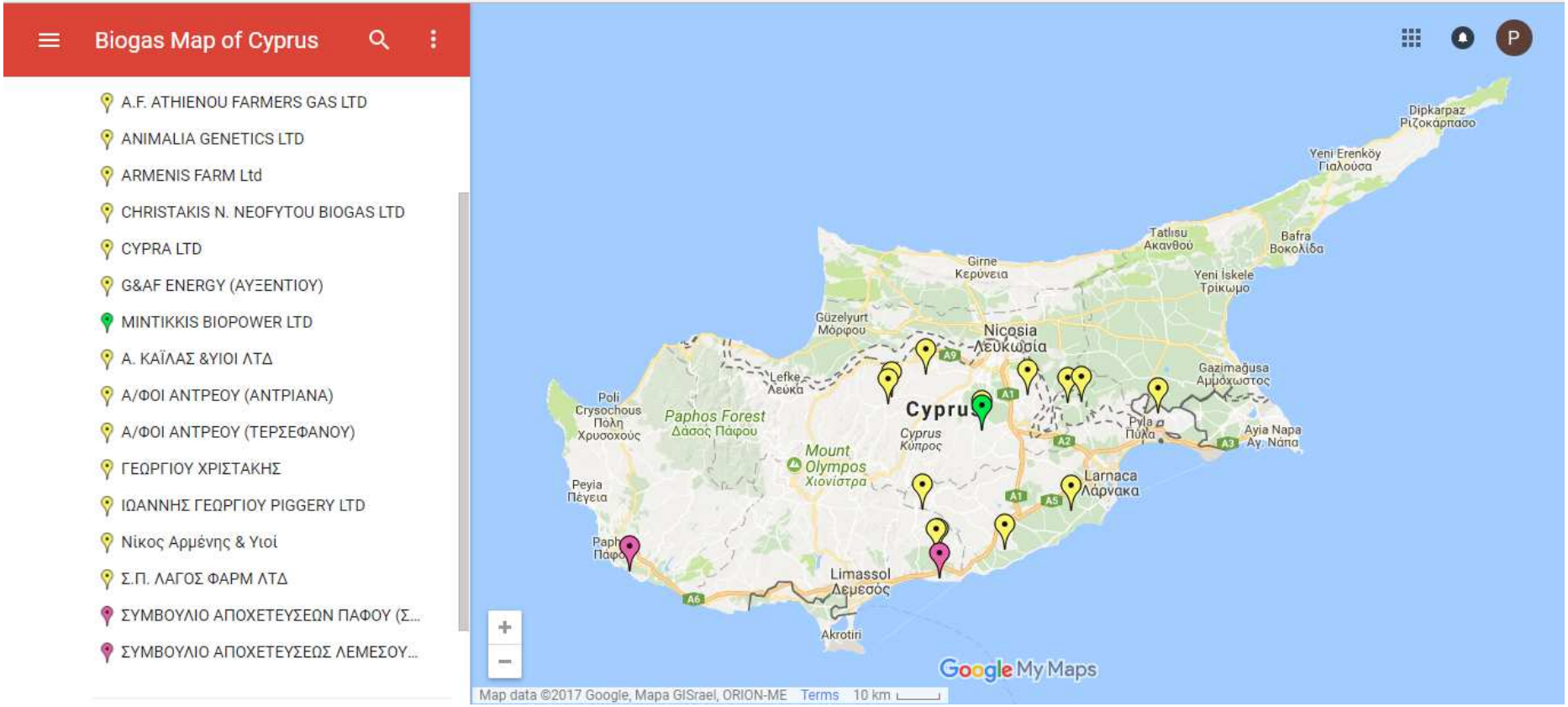
Biogas Plants in Europe (2015)



17,358 biogas plants in Europe (31/12/2015)
Total installed capacity of 8,728

1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

Biogas Map of Cyprus



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1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

COM(2015) 595 – Directive of the European Parliament and the council (amending directive 2008/98 on Waste)

- The weight of materials or substances that are not subject to a final recycling process and that are disposed or subject to energy recovery remains below 10% of the total weight to be reported as recycled

Link

1. European Acquis: Waste Management, Promotion of Energy Production with the use of Renewable Energy

COM(2017) 34 – The role of waste to energy in circular economy

Examples of waste-to-energy processes

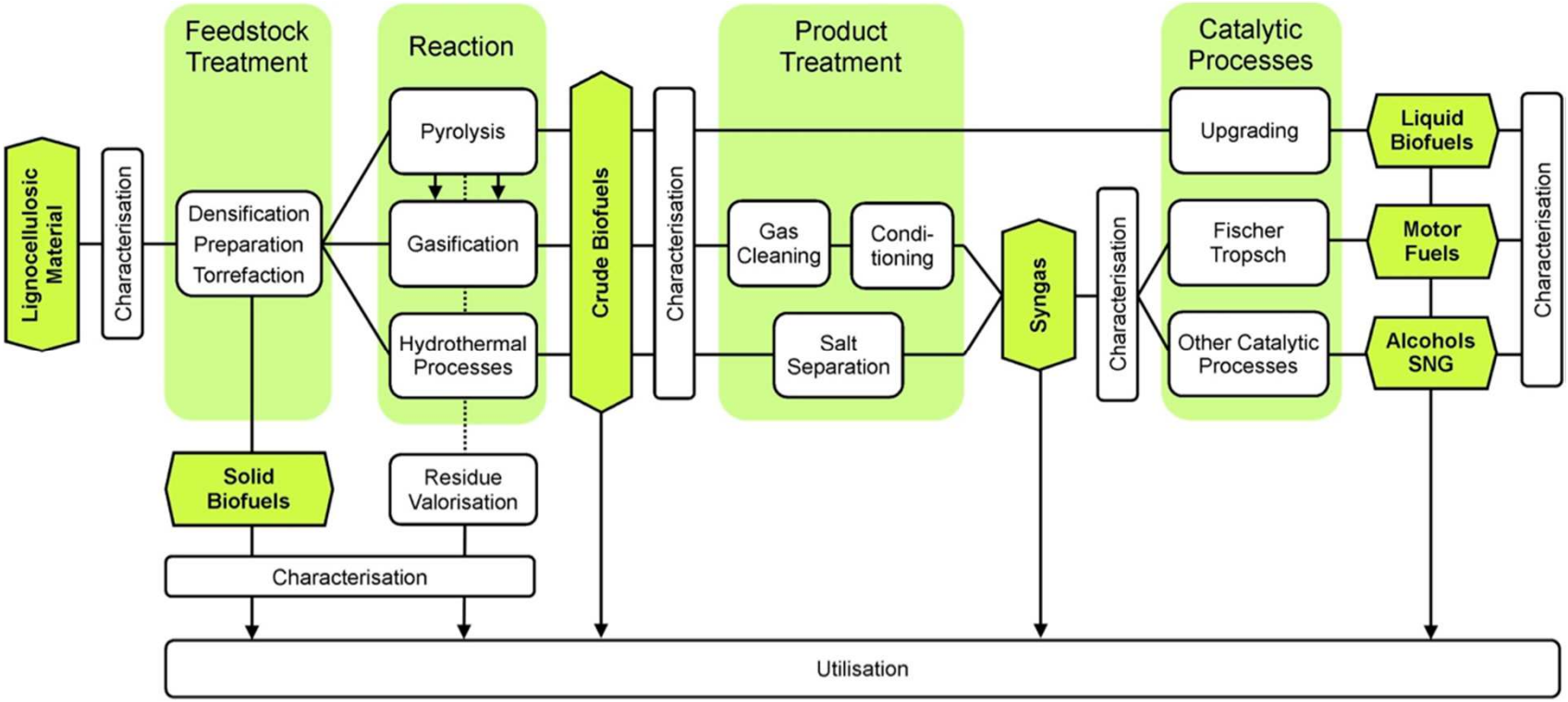
Anaerobic digestion of organic waste where the digestate is recycled as a fertliser

Waste incineration and co-incineration operations with a high level of energy recovery
Reprocessing of waste into materials that are to be used as solid, liquid or gaseous fuels

Waste incineration and co-incineration operations with limited energy recovery
Utilisation of captured landfill gas

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

Waste to Energy Technologies



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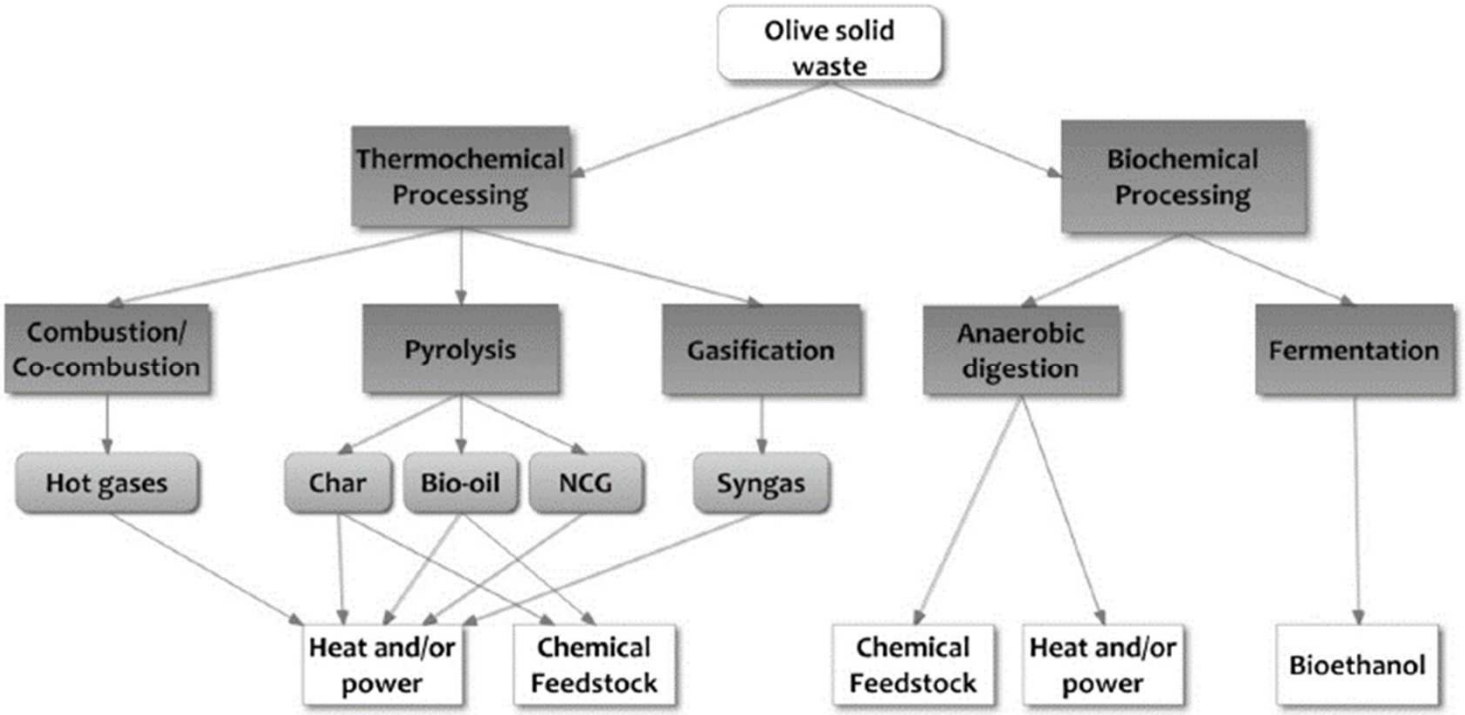
2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

Waste to Energy Technologies - OMSW



E. Christoforou, P.A. Fokaides / Waste Management 49 (2016) 346–363

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

Olive Mill Solid Waste

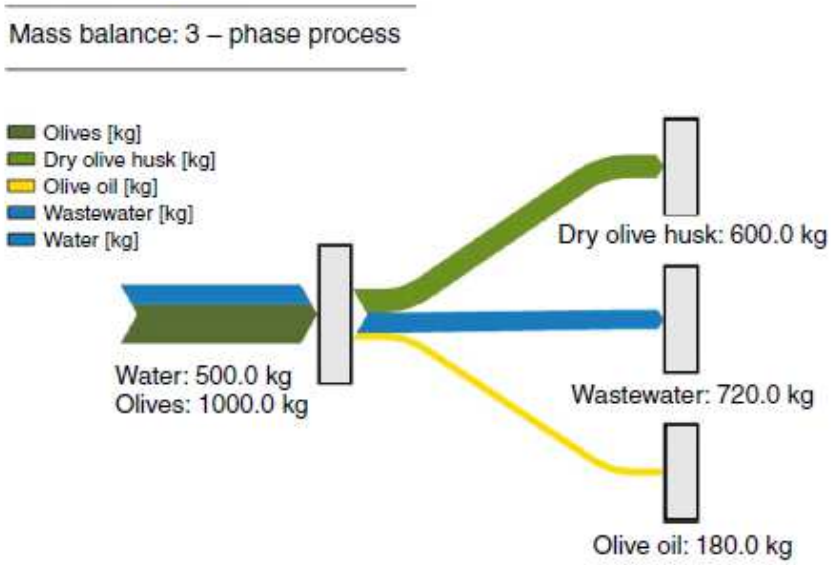


Fig. 1 Sankey diagram—three-phase olive oil extraction process

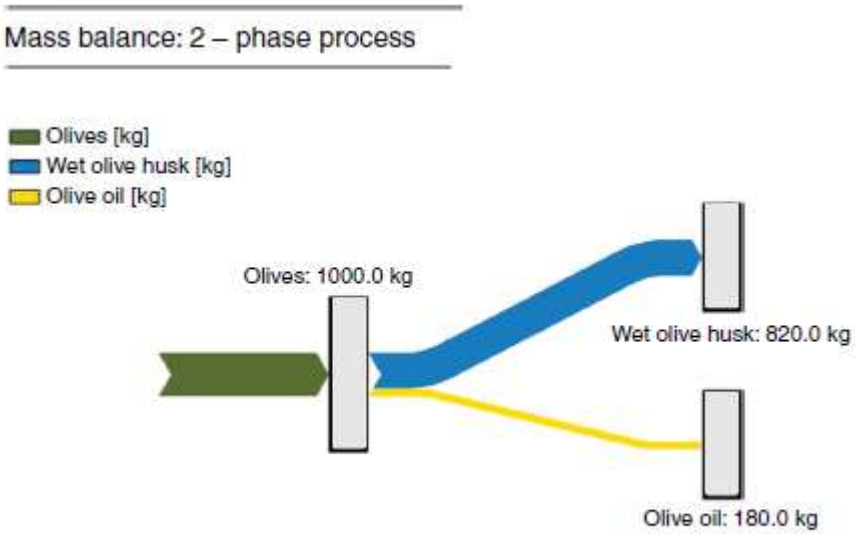
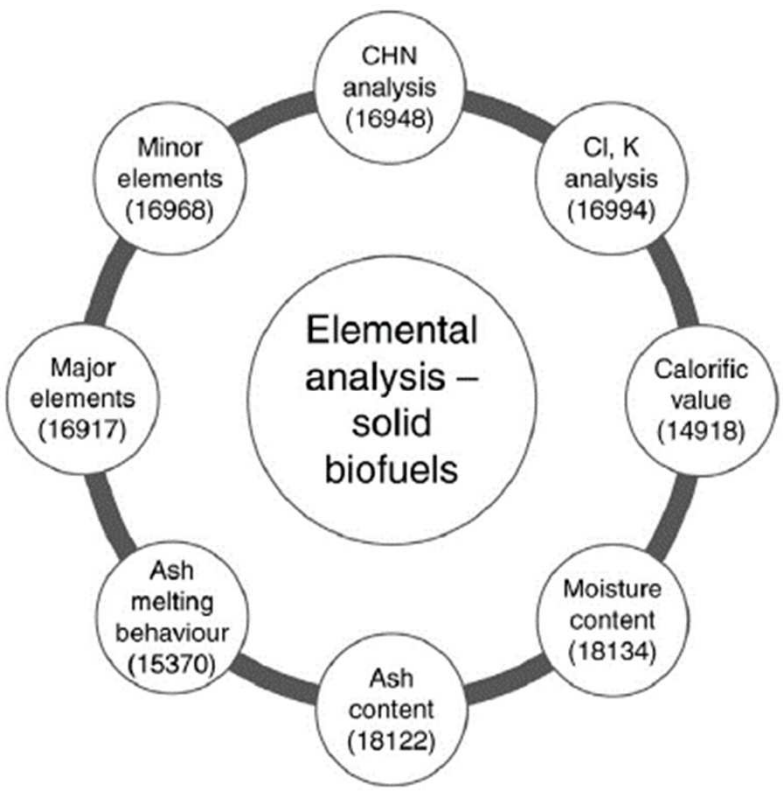


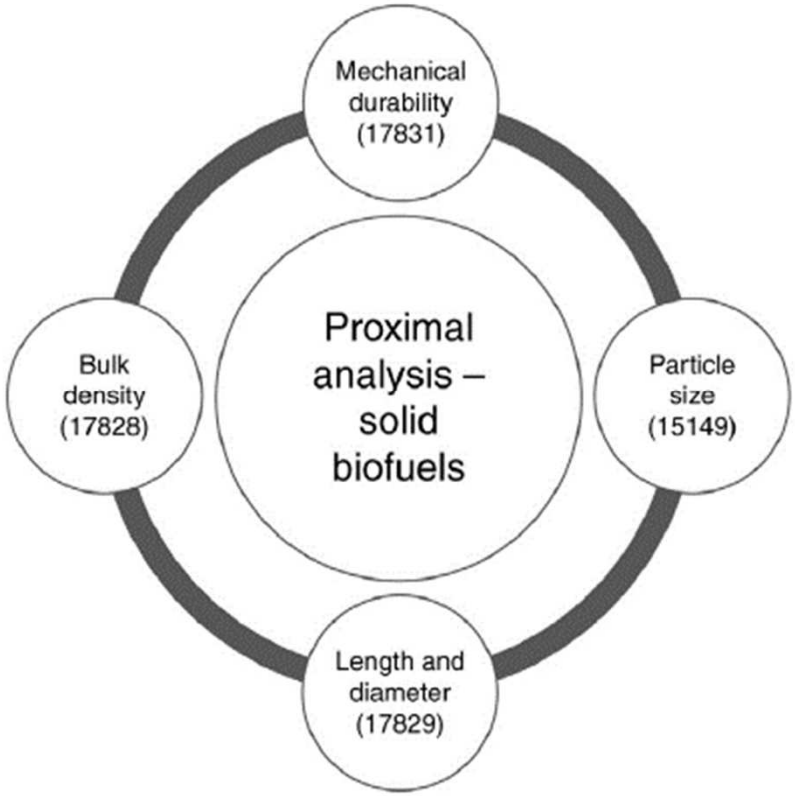
Fig. 2 Sankey diagram—two-phase olive oil extraction process

J Therm Anal Calorim (2014) 118:1789–1796

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

Elemental and Proximal Analysis Standardized Methods for Solid Biofuels





Fokaides, P.A. (2017). Energy recovery alternatives for the sustainable management of olive oil industry. In Olive Mill Waste, Recent Advances for Sustainable Management (pp 79–96). Academic Press.

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

Solid biofuels – Fuel specifications and classes (ISO 17225-1:2014)

3.2 By-products and residues from food and fruit processing industry	3.2.1 Chemically untreated fruit residues	3.2.1.1 Berries 3.2.1.2 Stone/kernel fruits/fruit fibre 3.2.1.3 Nuts and acorns 3.2.1.4 Crude olive cake 3.2.1.5 Blends and mixtures
	3.2.2 Chemically treated fruit residues	3.2.2.1 Berries 3.2.2.2 Stone/kernel fruits 3.2.2.3 Nuts and acorns 3.2.2.4 Exhausted olive cake 3.2.2.5 Blends and mixtures

Aristotle University of Thessaloniki

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

Solid biofuels – Fuel specifications and classes (ISO 17225-1:2014)

Table B.9 — Typical values for olive and grape cake

Parameter	Unit	Olive cake			Grape cake	
		Crude olive cake 3.2.1.4	Exhausted olive cake 3.2.2.4	Olive kernels 3.2.1.2	Crude grape cake 3.2.1.1	Exhausted grape cake 3.2.1.1, 3.2.2.1
Ash	w-% d	10	3,4 to 11,3	1,2 to 4,4	4,5 to 11,2	6 to 13
Gross calorific value $q_{V,gr,d}$	MJ/kg d	19,4 to 21,4	18,1 to 21,6	18,6 to 20,8	19,3 to 22,0	
Net calorific value $q_{p,net,d}$	MJ/kg d	18,1 to 20,7	13,9 to 19,2	17,3 to 19,3	16,7	19,0
Carbon, C	w-% d	50	48 to 52	45,7 to 52,3	54	46,0 to 54,4
Hydrogen, H	w-% d	6,9	4,6 to 6,3	6,1 to 6,8	6,8	5,8 to 7,5
Oxygen, O	w-% d	30	33	38,5 to 42,1	not specified	not specified

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Moisture Content and Elemental Analysis

Table 2 Moisture content (as received) determination, M_{ar}

A/A	Sub-sample	M_{ar}/%	Technology
1	NI 04_A	40.68	3-phase
2	NI 04_B	40.62	
3	NI 11_A	48.28	3-phase
4	NI 11_B	47.73	
5	PA 01_A	20.73	3-phase
6	PA 01_B	21.36	
7	PA 02_A	37.99	3-phase
8	PA 02_B	38.30	
9	FAM 01_A	44.60	3-phase
10	FAM 01_B	44.45	
11	FAM 02_A	48.77	3-phase
12	FAM 02_B	49.08	
13	LA 02_A	42.55	3-phase
14	LA 02_B	42.68	
15	LIM 02_A	39.94	3-phase
16	LIM 02_B	39.82	
17	LIM 04_A	58.29	2-phase
18	LIM 04_B	58.59	

Table 3 Elemental analysis results

A/A	Sub-sample	C/%	H/%	N/%
1	NI 04_A	47.69	5.93	0.42
2	NI 04_B	48.38	5.84	0.28
3	NI 11_A	49.11	6.68	0.48
4	NI 11_B	49.82	6.61	0.57
5	PA 01_A	49.31	5.95	0.25
6	PA01_B	49.12	5.91	0.24
7	PA 02_A	52.58	6.82	0.40
8	PA02_B	52.87	6.82	0.34
9	FAM 01_A	49.74	6.03	0.32
10	FAM 01_B	48.12	5.89	0.24
11	FAM 02_A	52.96	6.8	0.58
12	FAM 02_B	52.99	6.82	0.39
13	LA 02_A	53.74	6.67	0.40
14	LA 02_B	53.46	6.61	0.33
15	LIM 02_A	51.16	6.58	0.50
16	LIM 02_B	51.72	6.63	0.39
17	LIM 04_A	50.32	6.24	0.29
18	LIM 04_B	48.88	5.99	0.32

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2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Elemental Analysis and Calorific Value

Table 4 Comparison of mean values of C, H, and N content

C/%	H/%	N/%	Source
50.67	6.38	0.37	This study
52.80	6.69	0.45	Phyllis2 [40]
48.81	6.23	0.36	Phyllis2 [40]
47.07	5.95	2.40	Phyllis2 [40]
49.59	6.09	0.95	Phyllis2 [40]
51.38	6.32	0.45	BIOBIB [41]

Table 6 Comparison of olive husk calorific values

Calorific value/MJ kg^{-1}	Source
21.645	This study
21.61	Phyllis2 [40]
21.39	Phyllis2 [40]
18.70	Phyllis2 [40]
22.09	Phyllis2 [40]
21.60	BIOBIB [41]

J Therm Anal Calorim (2014) 118:1789–1796

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Life Cycle Assessment

$$min\left[\sum_{i=1}^{n} m_i{*}g{*}\left|\sqrt{|x_i-x|^2+|y_i-y|^2}\right| + \sum_{j=1}^{k} m_j{*}g{*}\left|\sqrt{|x_j-x|^2+|y_j-y|^2}\right|\right]$$

m_i Average annual quantity of olive husk for transportation to the MC, kg
m_j Average annual quantity of pellet for transportation from the MC, kg
x Cartesian coordinates of MC along x-axis, m (Annex, Table A3)
x_i Cartesian coordinates of olive mills along x-axis, m (Annex, Table A1)
x_j Cartesian coordinates of industrial zones along x-axis, m (Annex, Table A2)
y Cartesian coordinates of MC along y-axis, m (Annex, Table A3)
y_i Cartesian coordinates of olive mills along y-axis, m (Annex, Table A1)
y_j Cartesian coordinates of industrial zones along y-axis, m (Annex, Table A2)
g Gravity acceleration, 9.81 m s^{-2}

A. Kylili et al. / Biomass and Bioenergy 84 (2016) 107-117

2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Life Cycle Assessment

Coordinates of olive mills in Cyprus

Province	Olive oil mill	Latitude	x_i (Easting-UTM, m)	Longitude	y_i (Northing-UTM, m)
Ammochostos	1	35°02′31.20″N	578969.87	33°51′57.02″E	3878043.34
	2	35°01′22.04″N	571596.22	33°47′05.32″E	3875851.69
Larnaca	3	34°51′48.28″N	544374.58	33°29′07.73″E	3858003.51
	4	34°51′23.12″N	542453.14	33°27′51.91″E	3857219.24
	5	34°51′15.16″N	541942.31	33°27′31.75″E	3856971.80
	6	34°47′15.58″N	531351.56	33°20′33.68″E	3849549.39
	7	34°48′45.25″N	529508.36	33°19′21.50″E	3852305.48
	8	34°51′42.92″N	517472.19	33°11′28.15″E	3857747.6
Nicosia	9	34°57′08.22″N	527510.16	33°18′04.68″E	3867792.80
	10	34°59′06.50″N	532842.92	33°21′35.46″E	3871454.16
	11	35°04′10.85″N	489950.82	32°53′23.21″E	3880775.97
	12	35°04′05.09″N	489864.77	32°53′19.82″E	3880598.63
	13	35°02′16.12″N	490523.31	32°53′45.96″E	3877241.12
	14	35°08′01.46″N	511119.12	33° 7′19.38″E	3887881.18
	15	35°08′51.07″N	521562.22	33°14′12.19″E	3889428.25
	16	35°05′42.04″N	525402.42	33°16′43.32″E	3883615.03
	17	35°02′08.88″N	515226.06	33°10′00.95″E	3877025.89
	18	35°02′43.87″N	523202.6	33°15′15.88″E	3878120.60
	19	35°00′44.89″N	526771.46	33°17′36.33″E	3874465.21
	20	35°02′50.40″N	490604.4	32°53′49.12″E	3878296.97
	21	35°07′07.18″N	508490.59	33° 5′35.45″E	3886206.23
Paphos	22	35°00′03.42″N	449317.37	32°26′40.49″E	3873289.32
	23	34°59′28.79″N	449826.06	32°27′00.79″E	3872219.70
	24	34°55′23.54″N	460818.64	32°34′15.69″E	3864610.91
	25	34°44′39.55″N	454131.81	32°29′56.04″E	3844803.97
	26	34°44′44.98″N	455547.84	32°30′51.69″E	3845025.83
Limassol	27	34°40′46.02″N	476483.67	32°44′35.84″E	3837526.20
	28	34°45′24.73″N	478004.37	32°45′34.80″E	3846107.51
	29	34°40′51.81″N	493600.46	32°55′48.50″E	3837676.78
	30	34°50′48.48″N	515298.36	33°10′02.42″E	3856066.75
	31	34°43′37.38″N	495268.46	32°56′53.95″E	3842775.84

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2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Life Cycle Assessment

1. *Scenario 1*: Centralised management centre
2. *Scenario 2*: Decentralised management centres
3. *Scenario 3*: Centralised management centre incorporating Renewable Energy Sources (RES)
4. *Scenario 4*: Decentralised management centre incorporating Renewable Energy Sources (RES)

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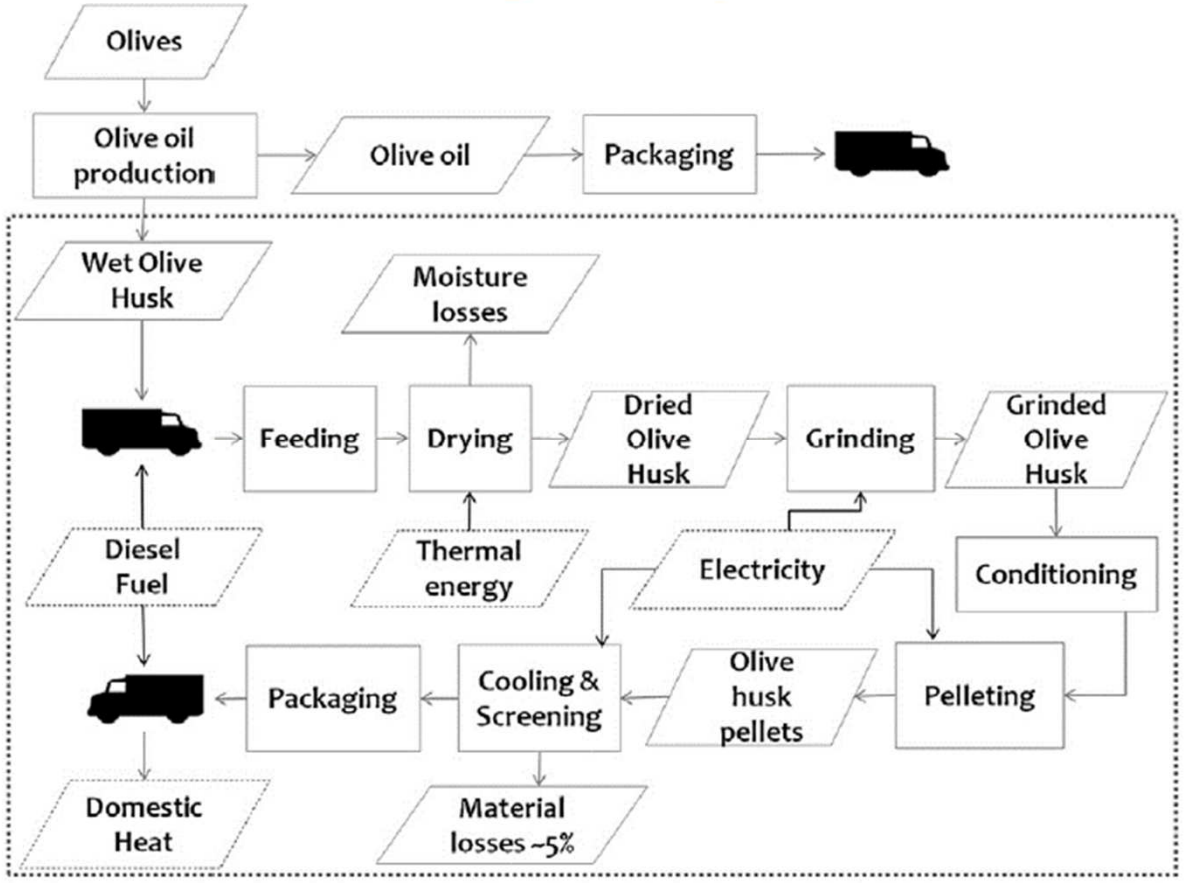
2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Life Cycle Assessment



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2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Life Cycle Assessment

Process & inputs	Value				Units	Description	Data source
	SC 1	SC 2	SC 3	SC 4			
Transport from olive mills to management centre							
Mass transported	1503.7	1503.7	1503.7	1503.7	kg	kg of waste olive husk	For the production of 1t of EN ISO 17225-6:2014 compliant non- woody pellets for non- industrial use
Diesel	173.6	46.3	173.6	46.3	MJ	Calculated considering the cargo weight and real distance	GaBi6 database
Transportation distance	1817.6	605.9	1817.6	605.9	km	Considering the location of management centre(s)	Google maps
Feeding							
Mass	1503.7	1503.7	1503.7	1503.7	kg	kg of waste olive husk entering the system	For the production of 1t of EN ISO 17225-6:2014 compliant non- woody pellets for non- industrial use
Drying							
Mass loss	30	30	30	30	%	Moisture content reduction from 45% wt to 15% wt	Technical data: Model: Phaethon 1 [49]
Grid electricity	324.8	252.6	–	–	MJ	For SC 1&3: Input: 9 kW; Output: 150 kg h^{-1} For SC 2&4: Input: 7 kW; Output: 150 kg h^{-1}	
Solar energy	–	–	324.8	252.6		For SC 3&4: Thermal energy provided by solar thermal collectors	GaBi 6 database
Grinding							
Grid electricity	189.5	139.0	–	–	MJ	For SC 1&3: Input: 7.5 kW; Output: 150 kg h^{-1} For SC 2&4: Input: 5.5 kW; Output: 150 kg h^{-1}	Technical data: Model: RS 650 [50]
Solar energy	–	–	189.5	139.0		For SC 3&4: Electricity provided by solar photovoltaics	
Pelleting							
Grid electricity	339.2	235.6	–	–	MJ	For SC 1&3: Input: 22 kW; Output: 250 kg h^{-1} For SC 1&3: Input: 7.5 kW; Output: 120 kg h^{-1}	Technical data: Model: AMP360c [51]
Solar energy	–	–	339.2	235.6		For SC 3&4: Electricity provided by solar photovoltaics	Type: Rotating roller

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2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Life Cycle Assessment

Cooling and screening							
Mass loss	5	5	5	5	%	Loose material loss	Empirical data [56],
Grid electricity	8.7	9.4	–	–	MJ	Input: 0.75 kW Output: 325 kg h^{-1}	Technical data: Model: ACC300 [51]
Solar energy	–	–	8.7	9.4		For SC 3&4: Electricity provided by solar photovoltaics	
Transport from management centre to sale points							
Mass transported	1000	1000	1000	10,000	Kg	Functional unit	For the production of 1t of EN ISO 17225-6:2014 compliant non- woody pellets for non- industrial use
Diesel	159.1	62.3	159.1	62.3	MJ	Calculated considering the cargo weight and distance	GaBi 6 database
Transportation distance	356.6	49.3	356.6	49.3	Km		Google maps

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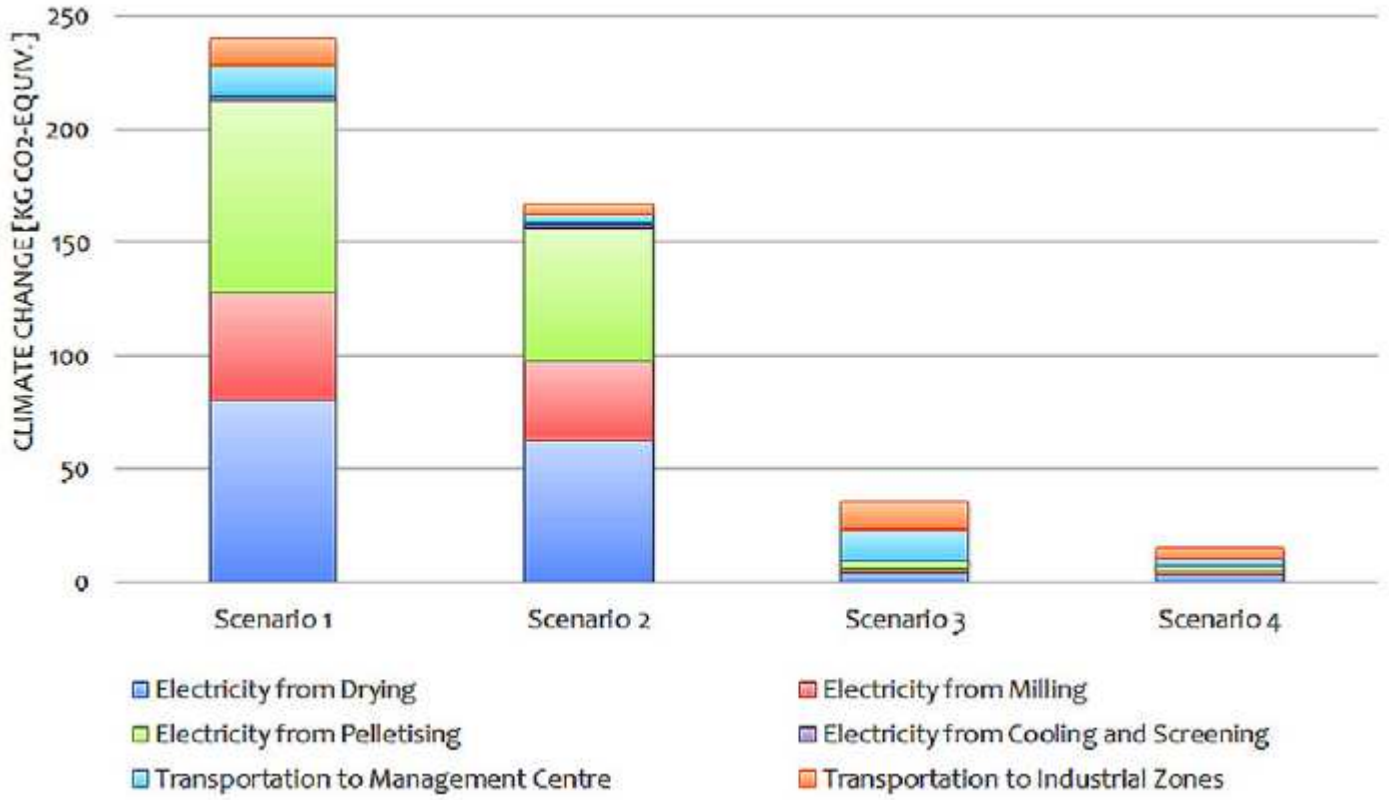
2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Life Cycle Assessment



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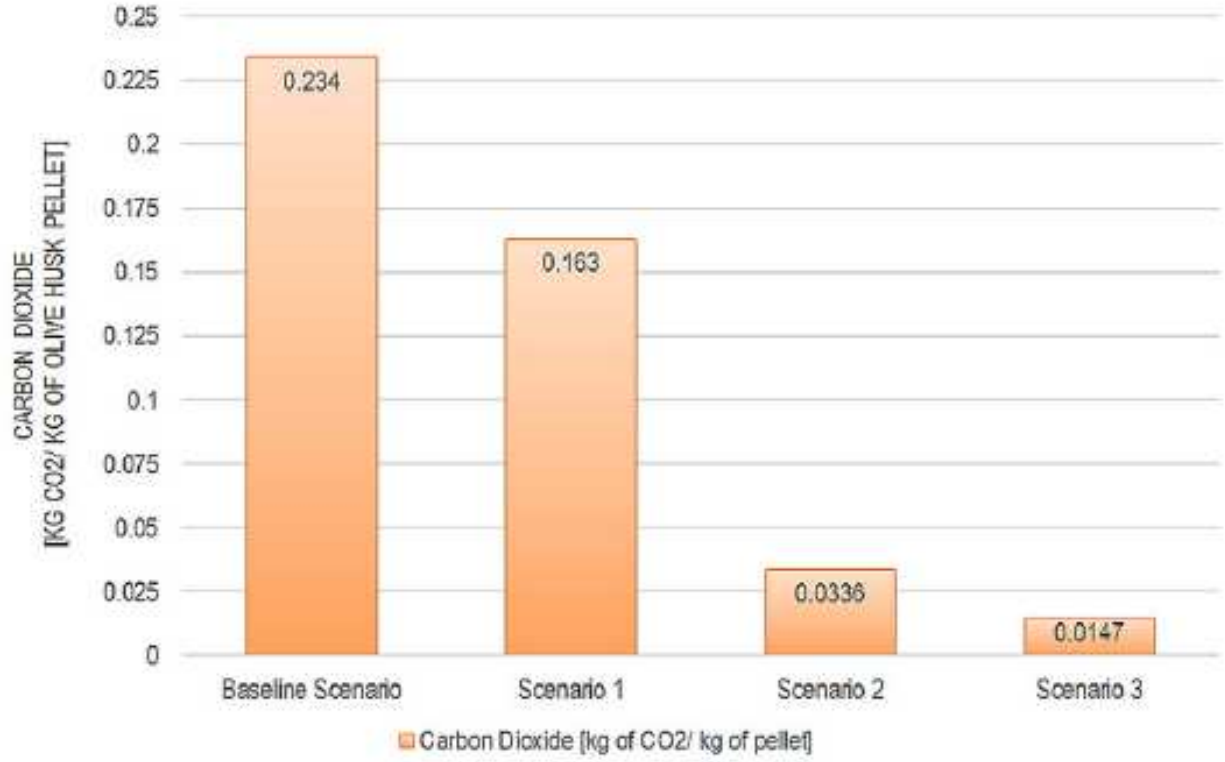
OMSW Collection and Processing – Life Cycle Assessment



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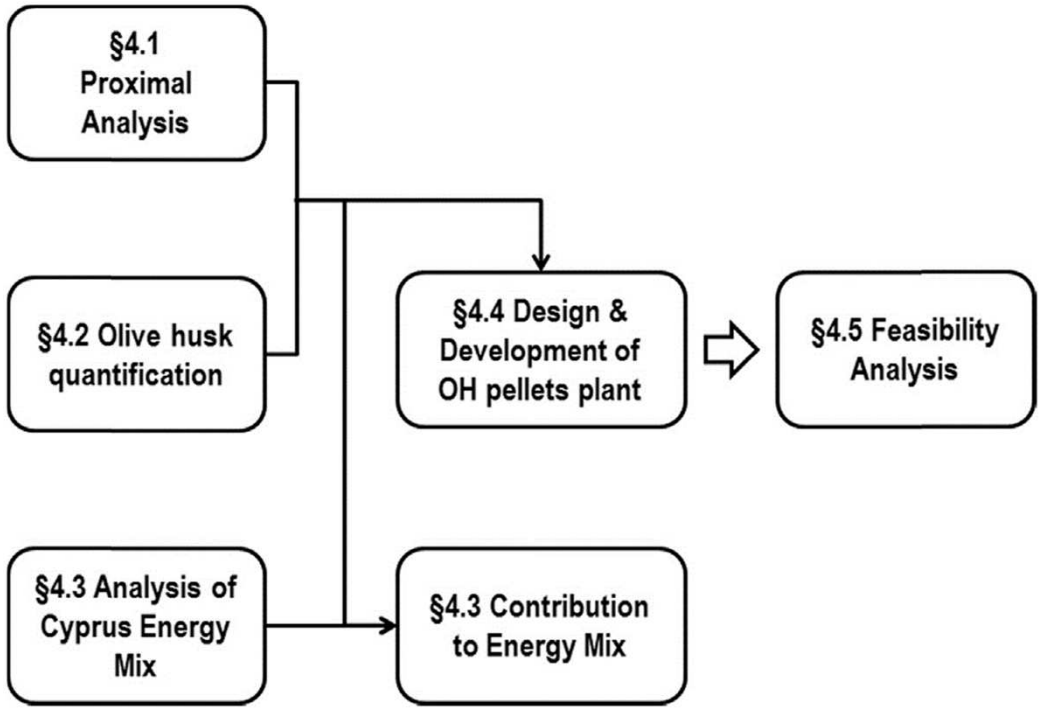
2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Feasibility Assessment



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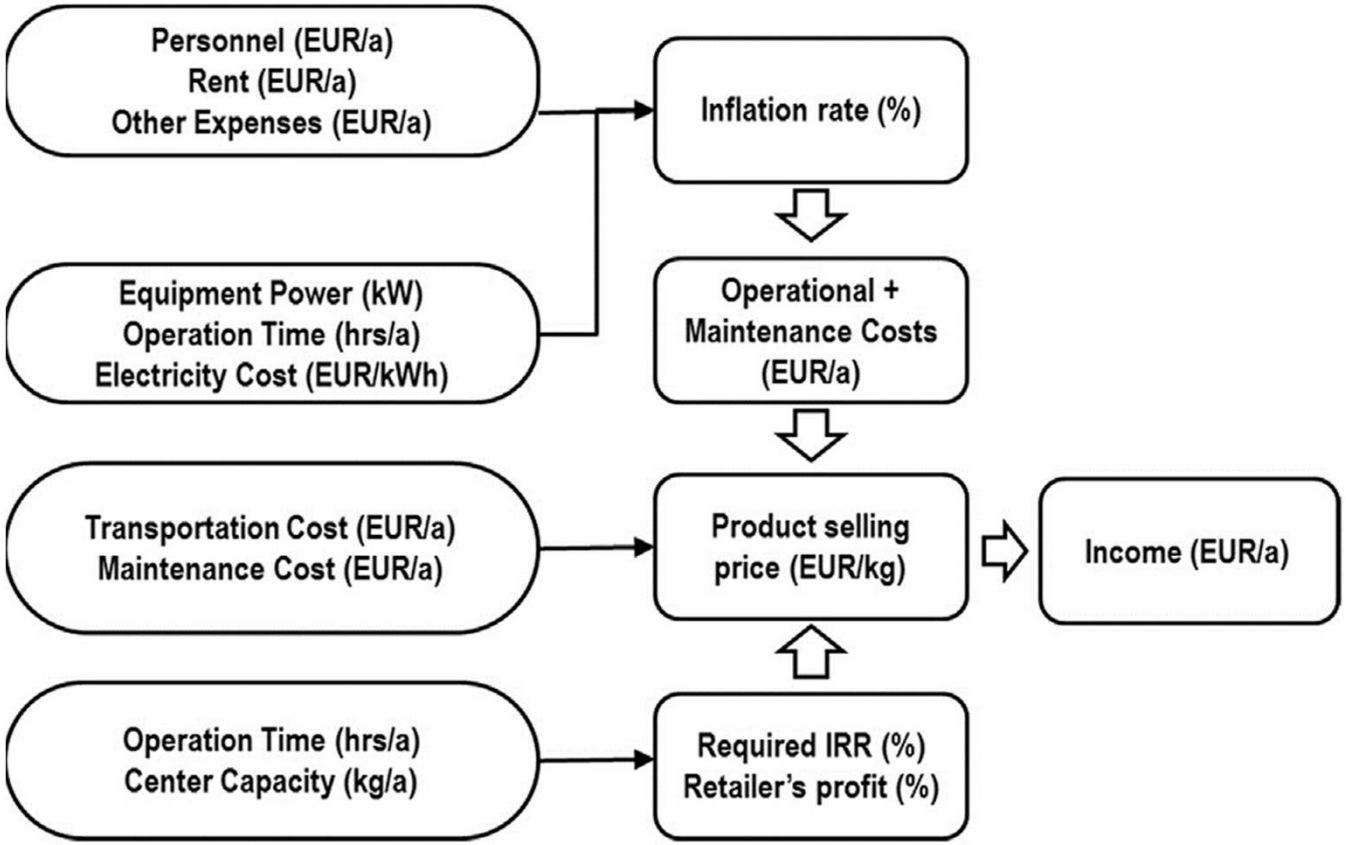
OMSW Collection and Processing – Feasibility Assessment



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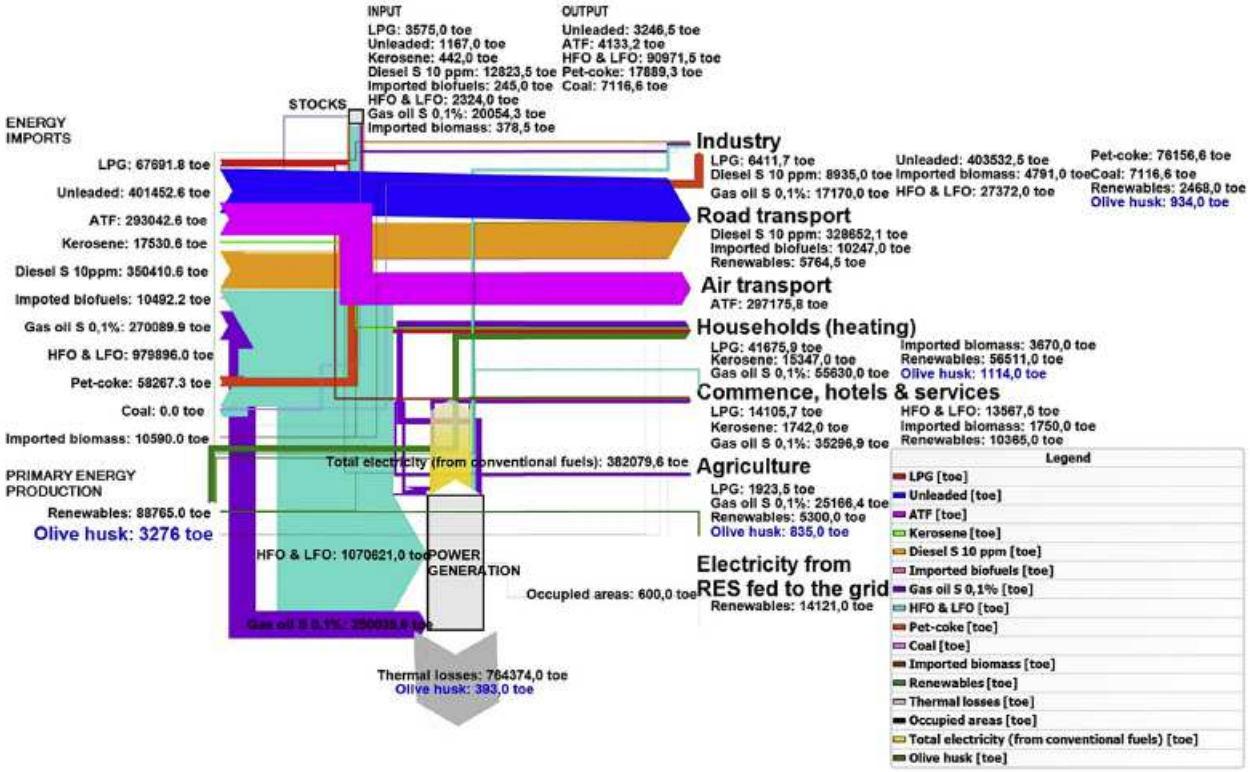
2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Feasibility Assessment



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2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Collection and Processing – Feasibility Assessment

Technical data of olive mills solid waste pellet plant equipment.

Equipment/property	Unit
Dryer	
Manufacturer	Litsakis Pantelis & Antonios O.E. (GR)
Model	Phaethon 1
Power	3 kW
Capacity	max 250 kg h^{-1}
Milling machine	
Manufacturer	KOVO NOVÁK (CZ)
Model	RS 650
Power	7.5 kW
Number of blades	18
Capacity	100–500 kg h^{-1}
Sieves size	4 mm
Cyclone power	2.5 kW
Pellet Mill	
Manufacturer	Laizhou Chengda Machinery Co., Ltd. (CN)
Model	AMP360c
Type	Rotating roller (3 rollers)
Power	22 kW
Capacity	220–500 kg h^{-1}
Pellet diameter	6 mm
Weighing and packaging assembly	
Manufacturer	Metrotech (GR)
Model	TEDEA 1263
Class	C3
Capacity	50–635 kg

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OMSW Collection and Processing – Feasibility Assessment

Assumptions taken into consideration for the feasibility analysis of the olive mills solid waste pellet production plant – Baseline case study.

Assumption	Value	Unit
Operation		
Investment	60,000	€
Instalments	326	€ $month^{-1}$
Inflation	3	%
Depreciation	20	years
Personnel[a,b]	2030	€ $month^{-1}$
Other cost	500	€ $month^{-1}$
Rent	250	€ $month^{-1}$
Power	50	kW
Electricity	0.2	€ kWh^{-1}
rowheadTransportation		
Average transportation distance	100	km
Truck capacity	20	tonnes
Diesel fuel cost	1.30	€ lt^{-1}
Fuel consumption (empty)[c]	23	lt 100 km^{-1}
Fuel consumption (full)[c]	32	lt 100 km^{-1}
Truck maintenance[d]	850	€
IRR	10%	%
NPV	4	%

[a] Two full-time employees.
[b] GDP [€] (nominal, 2013):26,389 [43].
[c] Data taken from Volvo Trucks webpage [44].
[d] Every 18,000 km.

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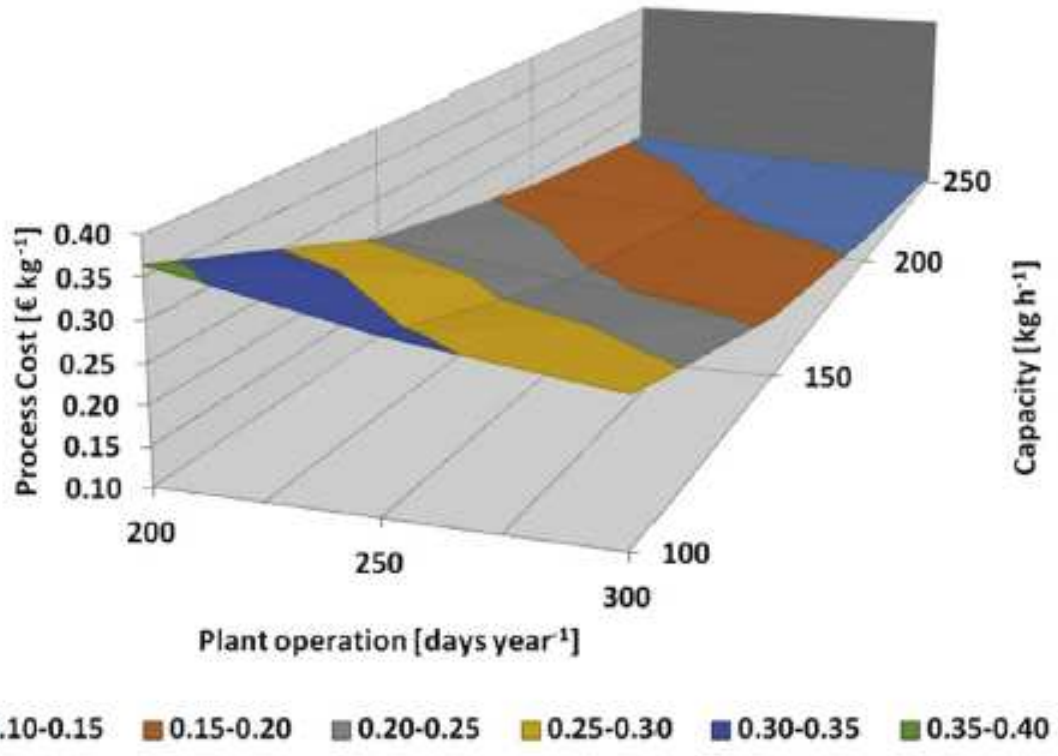

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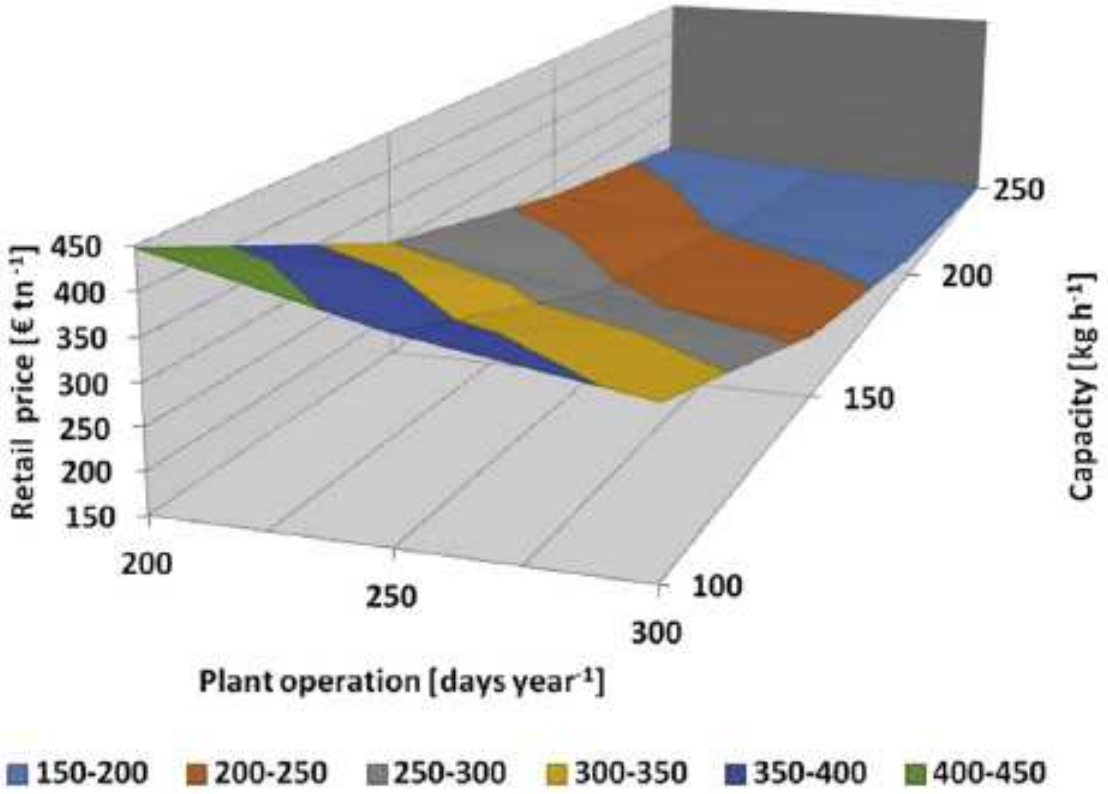

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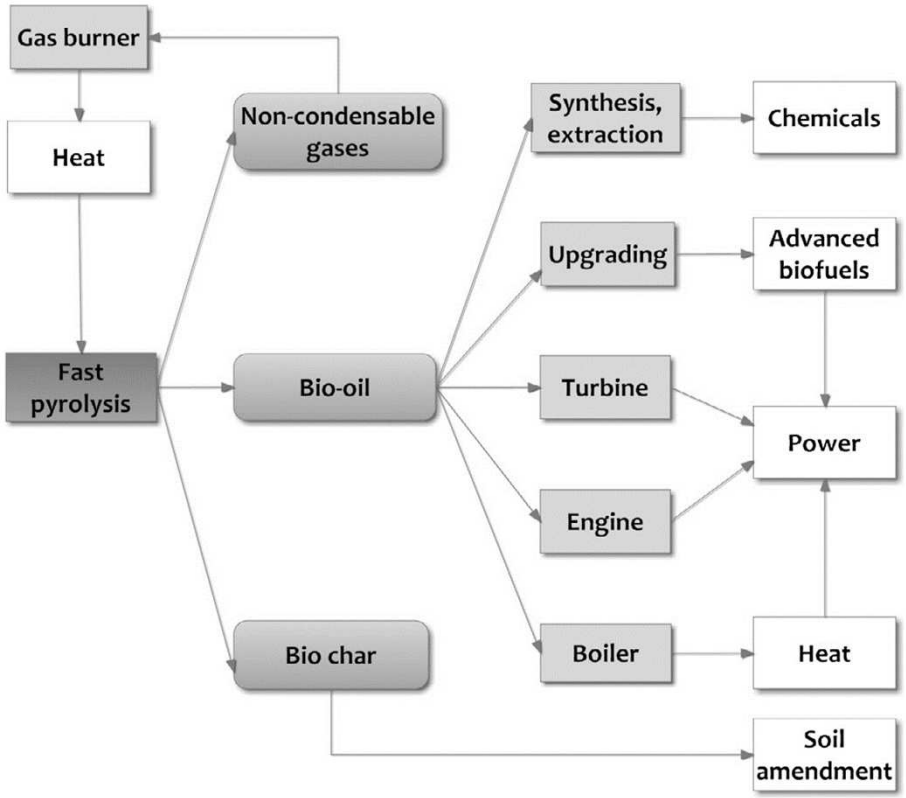
2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Fast Pyrolysis – Exploitation Options



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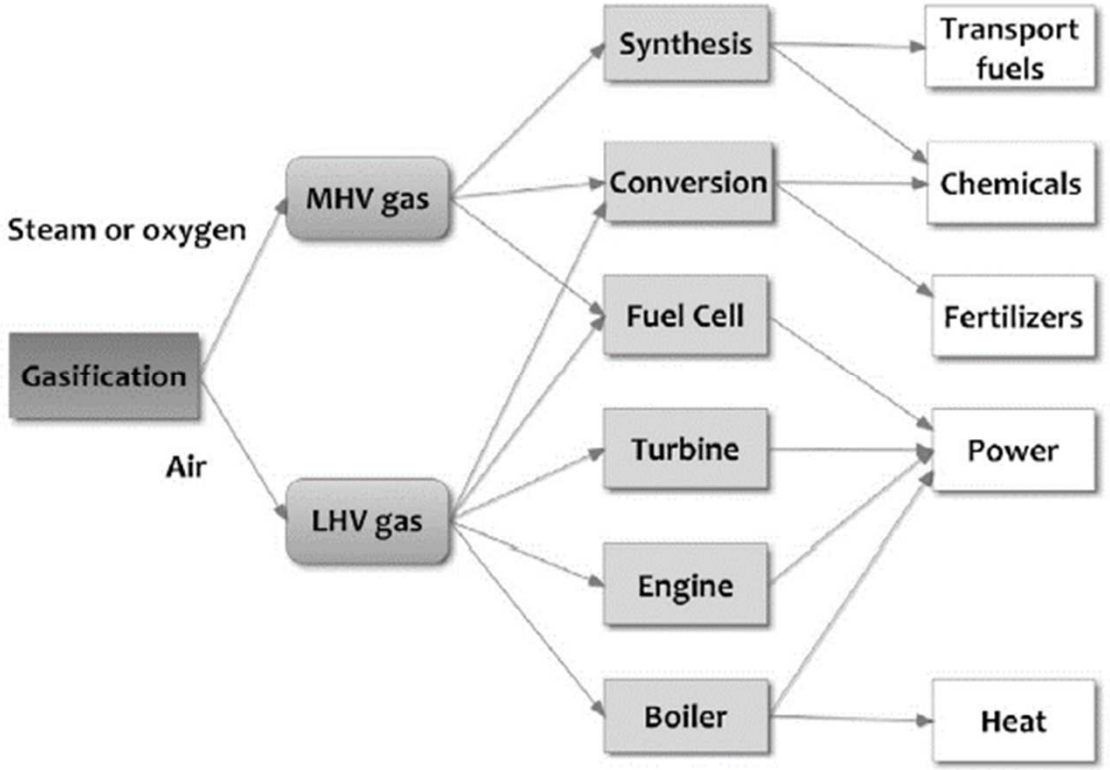
2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

OMSW Gasification – Exploitation Options



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2. Waste to Energy Technologies for Exploitation of Olive Mill Solid Waste (OMSW)

Suggested Literature

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- Christoforou, E. & Fokaides, P. A.(2016). Thermochemical Properties of Pellets Derived from Agro-residues and the Wood Industry. **Waste and Biomass Valorization**, 8, 1325–1330. link
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- Christoforou, E., & Fokaides, P. A. (2016). A review of olive mill solid wastes to energy utilization techniques. **Waste Management**, 49 346–363. link
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- Christoforou, E. A., Fokaides, P. A., & Kyriakides, I. (2014). Monte Carlo parametric modeling for predicting biomass calorific value. **Journal of Thermal Analysis and Calorimetry**, 118(3), 1789-1796. link

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3. Pilot station for OMSW pelleting

Media Presentation

- https://www.youtube.com/watch?v=2QId0Qs1LEY&t=6s

4. Q+A

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For further information

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SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Thank you for your attention.

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