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for the Environment, Nature Conservation
and Nuclear Safety

ΥΠΟΥΡΓΕΙΟ
ΠΕΡΙΒΑΛΛΟΝΤΟΣ
& ΕΝΕΡΓΕΙΑΣ

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

Guidance to develop by-products and end-of-waste criteria and proposals for draft legislation in Greece

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Final Report

26th March 2021

Clean Energy

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LIST OF MAIN ABBREVIATIONS

AD	ANAEROBIC DIGESTION
BOD	BIOLOGICAL OXYGEN DEMAND
COD	CHEMICAL OXYGEN DEMAND
CSAM	COLLECTIVE SYSTEM FOR ALTERNATIVE MANAGEMENT
CSTR	CONTINUOUS-FLOW STIRRED TANK REACTOR
CW	CHEESE WHEY
DWR	DIGITAL WASTE REGISTRY
EC	EUROPEAN COMMISSION
ELSTAT	HELLENIC STATISTICAL AUTHORITY
ELTS	END-OF-LIFE TYRES
EOAN	HELLENIC RECYCLING AGENCY
EPR	EXTENDED PRODUCER RESPONSIBILITY
ETRMA	EUROPEAN TYRE & RUBBER MANUFACTURERS ASSOCIATION
EU	EUROPEAN UNION
EWC	EUROPEAN WASTE CATALOGUE

GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
HABio	Hellenic Association of Biogas Producers
JMD	Joint Ministerial Decision
KoM	Kick-Off Meeting
MD	Ministerial Decision
MITECO	Ministry for the Ecological Transition and the Demographic Challenge (Spain)
MSW	Municipal Solid Waste
NCV	Net Calorific Value
NWMP	National Waste Management Plan
RDF	Refuse Derived Fuel
SPEL	Association of Greek Pomace Oil Producers
SRF	Solid Recovered Fuel
TDA	Tyre Derived Aggregate
TDF	Tyre Derived Fuel
TDRM	Tyre-Derived Rubber Materials
ToRs	Terms of Reference
UASB	Anaerobic Sludge Blanket Reactor
WP	Whey Permeate
WPC	Whey Protein Concentrate
WPI	Whey Protein Isolate
YPEN	Ministry of Environment and Energy

Background and disclaimer

The competent Greek Authorities approached the European Commission (EC) for support in specific areas aiming for improvement of the implementation of the National Waste Management Plan (including the improvement of municipal waste management, regulatory issues of the waste sector, the management of specific waste categories) in order to raise the quality and quantity of recycling, to improve data quality and to effectively use economic instruments. To achieve the aforementioned goals, the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) provides "Technical support for the implementation of the National Waste Management Plan (NWMP) of Greece" from January 2019 to March 2021. The project is funded by the European Union (EU) via the Structural Reform Support Programme (SRSP) and the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU), and jointly implemented by GIZ and the Hellenic Ministry of Environment and Energy (YPEN), in collaboration with the EC.

GIZ commissioned Clean Energy Ltd. to provide specific technical expertise to GIZ and YPEN from January to March 2021 by implementing the project 'Guidance to develop by-products and end-of-waste criteria and proposals for draft legislation in Greece''. The hereby Final Report outlines the methodology and approach of the analysis of the involved tasks and activities. In particular, the study entails a) development of by-products criteria and legislation amendments on residues from olive oil production (e.g. oil pomace) and residues from the dairy industry for cheese or casein production (e.g. whey), and b) development of end-of-waste criteria and legislation amendments for rubber material derived from used tyres. Concrete recommendations for drafting a Joint Ministerial Decision (JMD) are provided.

Assignment	**Guidance to develop by-products and end-of-waste criteria and proposals for draft legislation in Greece**
Contract No.	81265763
Project Name	Technical support for the implementation of the National Waste Management Plan (NWMP) of Greece (68.3045.9)
Client / Project Executing Agency	**Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH** (GIZ) Project Manager: Ulrich Laumanns (ulrich.laumanns@giz.de) Senior Adviser: Vasiliki Panaretou (vasiliki.panaretou@giz.de) Senior Adviser: Maria Pisimisi (maria.pisimisi@giz.de)
Consultant	**Clean Energy Ltd.** Panagiotis Grammelis (grammelis@certh.gr) – rubber material from end-of-life tyres Manolis Karampinis (karampinis@certh.gr) – oil pomace and whey
Contract term	04.01.2021 - 26.03.2021

Disclaimer

Clean Energy Ltd. has taken due care in the preparation of this report to ensure that all facts and analysis presented are as accurate as possible within the scope of the study. However, no guarantee is provided in respect of the information presented, and Clean Energy Ltd. is not responsible for decisions or actions taken on the basis of the content of this report.

This document was produced with the financial assistance of the European Union. The views expressed herein can in no way be taken to reflect the official opinion of the European Union.

1. Introduction

The present document constitutes the Final Report prepared by Clean Energy under the assignment "Guidance to develop by-products and end-of-waste criteria and proposals for draft legislation in Greece" within the project Technical support for the implementation of the National Waste Management Plan (NWMP) of Greece (68.3045.9) implemented by GIZ and in relation to the improvement of the National Waste Management Plan (NWMP).

In particular, the assignment aims to offer specialized technical support to YPEN, the competent Greek authorities and stakeholders regarding three specific residual streams that are considered as of particular importance to the Ministry, in particular:

- Residues from the olive oil production value chain (e.g. oil pomace).
- Residues from the dairy industry for cheese or casein production (e.g. cheese whey).
- Rubber material derived from used tyres.

Clean Energy provided concrete proposals for the drafting of new JMDs for the development of by-product characterization criteria or end-of-waste criteria for these residual streams, as appropriate and according to the specifications of the Terms of Reference for this assignment.

Clean Energy implemented the assignment ensuring an integrated, holistic approach in line with the EU legislation and regulations. Guidance is provided on the transfer good practices and lessons learnt from other EU countries with similar conditions, while also developing solutions that are adjusted to the Greek market context and provide local know-how.

The level of analysis of our work for the development of by-products and end-of-waste criteria and proposals for draft legislation in Greece is according to the allocated efforts and scope of deliverables as stipulated in the Terms of Reference for this assignment. The Final Report also considers several points raised and discussed during the kick-off (11.01.2021) and final meeting (17.03.2021) with YPEN and GIZ, as well as in several email exchanges during the period of the assignment.

2. Preparation, stakeholder meetings, data collection and analysis

2.1 Stakeholders contacted

The following paragraphs provide an overview of key stakeholders and various market actors that were contacted for the purposes of the present assignment and that have provided useful feedback and comments.

2.1.1 Olive oil production residues

For olive pomace and olive oil / olive pomace-oil production residues the main stakeholder contacted was the Association of Greek Olive Pomace-Oil Producers (SPEL), which represents the olive pomace mill sector in Greece. SPEL provided insights regarding the olive pomace market structure in Greece and several members of the association have reviewed, provided feedback and suggestions for the section of this covering olive pomace and related residues, as well as on the formulation of the draft JMD. Through SPEL, earlier opinions of associations of olive pomace oil producers in Spain (ANEO - www.aneorujo.es), Italy (ASSITOL - www.assitol.it) and ANIDA (Portugal) on the subject of characterization of olive pomace as a by-product were provided.

Some additional stakeholders / market actors consulted for the purpose of this assignment include:

- The Spanish Bioenergy Association (AVEBIOM) – www.avebiom.org as regards the market situation in Spain and fuel quality parameters of exhausted olive cake and olive stones.
- The Hellenic Association of Biogas Producers (HABio) – www.habio.gr, representing biogas plants that may olive pomace and/or olive mill wastewater as a substrate for biogas production.

2.1.2 Cheese production residues

For cheese whey, the absence of an association explicitly representing cheese producers in Greece is noted. Therefore, emphasis was placed in contacting specific companies / enterprising producing and/or valorising cheese whey, such as:

- The Agricultural Dairy Cooperative of Kalavryta (www.kalavritacoop.gr) as an important manufacturer of cheese and whey cheeses, as well as operator of a biogas plant and supplier of whey to a nearby protein extraction plant.
- The Hellenic Association of Biogas Producers (HABio) – www.habio.gr, representing the plants that utilize cheese whey and/or secondary cheese whey as a substrate for biogas production.
- The Spanish Biogas Association (AEBIG) – www.aebig.org, regarding the status of cheese whey utilization in biogas plants in Spain.

2.1.3 Rubber from End-of-Life Tyres (ELTs)

For rubber derived from ELTs, the situation is more clear-cut, since Greece already implements an alternative management scheme for used tyres through ECOELASTIKA S.A. – www.ecoelastika.gr.

ECOELASTICA has reviewed, provided feedback and suggestions for the section of this covering rubber from end-of-life tyres, as well as on the formulation of the draft JMD on end-of-waste criteria for rubber derived from end-of-life tyres.

2.2 Literature sources

In addition to own knowledge and contacts with the stakeholders indicated in the previous sections, several data sources including project reports and scientific articles were consulted. Some relevant sources already identified at the start of the assignment include:

- European Commission - Guidelines on the interpretation of key provisions of Directive 2008/98/EC on waste (Not legally binding)[1]
- Biomasud Plus project Deliverable 2.1: Residential heating biofuels market state of the art report (2017)[2]
- AGROinLOG project Deliverable 6.1: Basic analysis of targeted agricultural sectors – Full Report_All countries (2017)[3]
- FOODINBIO[4] project Deliverable 1.2: Παγκόσμια Ανασκόπηση Χρήσης Τεχνολογιών Βιολογικής Επεξεργασίας για τη Διαχείριση Οργανικών Αποβλήτων από Βιομηχανίες Τροφίμων / Καταγραφή Βέλτιστων Διαθέσιμων Τεχνικών Διαχείρισης Οργανικών Αποβλήτων από Βιομηχανίες Τροφίμων– Ποτών (2014) – in Greek
- Valta K. et al. (2017) Current Treatment Technologies of Cheese Whey and Wastewater by Greek Cheese Manufacturing Units and Potential Valorisation Opportunities, Waste Biomass Valor 8:1649–1663, DOI 10.1007/s12649-017-9862-8
- End-of-Waste Criteria from JRC (Joint Research Center), Final Report, 2009, (EUR 23990 EN)[5]
- Report of the joint workshop "Waste/End of Waste", 19-20 April 2018 ARPA Veneto- Treviso Department headquarters - Italy
- End of waste criteria for the production and use of tyre-derived rubber materials (TDRM) produced from Natural Resources Wales, Environment Agency and Northern Ireland Environment Agency
- WRAP (Waste & Resources Action Programme) and the Environment Agency. 2009. Tyre-derived rubber materials: End of waste criteria for the production and use of tyre-derived rubber materials. Quality Protocol. Available at http://www.wrap.org.uk/content/quality-protocols
- Zorpas A. (2016) Sustainable waste management through end-of-waste criteria development, Environ Sci Pollut Res 23:7376–7389, DOI 10.1007/s11356-015-5990-5

Additional reference sources identified and used during the implementation of the assignment are added as footnotes in this report.

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[1] http://waste-prevention.gr/waste/wp-content/uploads/2015/10/2012_Guidance%20interpretation%20Directive%2098-2008-EC_EN.pdf (last accessed on 26 March 2021)

[2] http://biomasudplus.eu/wp-content/uploads/2017/09/D2.1-Market_report_Consolitated-6.pdf (last accessed on 26 March 2021)

[3] http://agroinlog-h2020.eu/wp-content/uploads/2017/05/AGROinLOG_D6.2_Basic-analysis-of-targeted-agricultural-sectors_FV.pdf (last accessed on 26 March 2021)

[4] http://foodinbio.uest.gr/index.php/en/ (last accessed on 26 March 2021)

[5] http://publications.jrc.ec.europa.eu/repository/handle/JRC53238 (last accessed on 26 March 2021)

3. Olive oil and olive pomace-oil production residues

Olive pomace is the main residue from the olive oil production process that takes place in the olive oil mills. Considering an average olive oil yield of 20 % and the fact that olive pomace contains almost all the remaining parts of the olive fruit, it is quite clear that the volumes of olive pomace generated during each campaign season are huge and required proper handling so that they do not represent an environmental hazard.

3.1 Definitions

The olive oil production process produces various residues, the management of which produces other various residual streams. Different terms are applied on a national or sometimes even regional level to label these resides. For the purposes of this study and in order to avoid confusion, we provide the following definitions:

Olive paste: the material that occurs after the crushing of the olive fruit in the olive oil production process.

Olive pomace: the material that occurs after the separation of the olive oil from the olive paste. Olive pomace consists of the skin, flesh and crushed stone of the olive fruit and contains some residual oil as well as a varying content of water, depending on the process.

Press olive pomace: the olive pomace that occurs from the “traditional”, press olive oil production process (see Section 3.2). The moisture content of press olive pomace is typically between 25 - 35 w-% and the residual oil content is around 3.0 – 9.0 w-%.

Two-phase olive pomace: the olive pomace that occurs from the two-phase olive oil production process (see Section 3.2). The moisture content of two-phase olive pomace is typically between 60 - 70 w-% and the residual oil content is around 2.0 – 3.5 w-%.

Three-phase olive pomace: the olive pomace that occurs from the three-phase olive oil production process (see Section 3.2). The moisture content of three-phase olive pomace typically ranges between 45 – 55 w-% and the residual oil content is around 2.5 – 6 w-%.

Dry olive pomace: the olive pomace that has undergone a drying step through the use of hot gas streams or other methods in order to reduce its moisture content.

Exhausted olive pomace / exhausted olive cake: the solid residue that occurs from the dry olive pomace after extraction of the raw olive pomace oil.

Olive stones: the crushed endocarp of the olive fruit that can be separated from the olive paste, olive pomace or exhausted olive cake.

Crude olive-pomace oil: the oil extracted from various types of olive pomaces through various appropriate physical or chemical processes.

Refined olive-pomace oil: the oil that occurs from the raw olive pomace oil after a refining process in appropriate facilities.

Olive mill effluents: general term for various wastewater streams that may be generated during various steps of the olive oil production process, e.g. wastewater from olive fruit washing, wastewater separated from the olive pomace in three-phase production systems, wastewater from olive oil washing.

The following table presents the terms used for these streams in Greek, Spanish and Italian, e.g. in the languages of the main EU olive oil producers. Some colloquial terms and expressions are also provided.

It should be noted that on the EU-level there are exact definitions only for crude olive-pomace oil and refined olive-pomace oil in Annex XVI of COUNCIL REGULATION (EC) No 1234/2007 of 22 October 2007 establishing a common organization of agricultural markets and on specific provisions for certain agricultural products (Single CMO Regulation). Crude olive-pomace oil and refined olive-pomace oil may not be marketed at the retail stage.

Table 1: Terms used for various residual streams and products from the olive oil production.

English	Greek	Spanish	Italian
Olive pomace	Ελαιοπυρήνας	Orujo de Oliva	Sansa di olive
Two-phase olive pomace	Διφασικός ελαιοπυρήνας	Orujo graso húmedo / Alpeorujo	Sansa umida (da sistema di estrazione a due fasi)
Three-phase olive pomace	Τριφασικός ελαιοπυρήνας	Orujo graso	Sansa (da sistema di estrazione a tre fasi)
Olive stones	Κουκούτσι ελιάς / «Ξυλάκι»	Huesos de aceituna	Nocciolino di olive
Dry olive pomace	Ξηρός ελαιοπυρήνας	Orujo graso seco	Sansa secca
Exhausted olive pomace / exhausted olive cake	Εκχυλισμένος ελαιοπυρήνας; Πυρηνόξυλο	Orujillo	Sansa esausta
Crude olive-pomace oil	Ακατέργαστο πυρηνέλαιο	Aceite de orujo de oliva crudo	Olio di sansa di oliva greggio
Refined olive-pomace oil	Εξευγενισμένο πυρηνέλαιο	Aceite de orujo de oliva refinado	Olio di sansa di oliva raffinato
Olive mill effluents	Υγρά απόβλητα ελαιοτριβείου / Κατσίγαρος / Λιόζουμα / Μούργα	Alpechin	Acqua di vegetazione

In addition to the above, Commission Regulation (EU) No 68/2013 of 16 January 2013 on the Catalogue of feed materials includes in its list of feed materials three items that are obtained from residual streams of the olive oil industry. A summary is provided in the table below. A common feature of all three materials is the separation of the kernel (stone) to the extent that is possible.

Table 2: Feed materials from olives according to Regulation 68/2013.

Number	Name	Definition	Compulsory declarations
2.11.1	Olive pulp (EN) Ελαιάλευρο (GR) Sansa di olive (IT) Orujo de aceituna deshuesada (ES)	Product of oil manufacture, obtained by extraction of pressed olives Olea europea L. separated as far as possible from parts of the kernel	Crude protein Crude fibre Crude fat
2.11.2	Defatted olive meal feed (EN) Ζωοτροφή ελαιάλευρου χωρίς λιπαρά (GR) Mangimi di farina d'oliva sgrassata (IT) Alimento de harina de aceituna desgrasada (ES)	Product of olive oil manufacture, obtained by extraction and appropriate heat treatment of olive pulp expeller separated as far as possible from parts of the kernel. May contain up to 1 % used bleaching earth and filter aid (e.g. diatomaceous earth, amorphous silicates and silica, phyllosilicates and cellulosic or wood fibres) and crude lecithins from integrated crushing and refining plants	Crude protein Crude fibre
2.11.3	Defatted olive meal (EN) Ελαιάλευρο χωρίς λιπαρά (GR) Farine di oliva sgrassate (IT) Harina de aceituna desgrasada (ES)	Product of olive oil manufacture, obtained by extraction and appropriate heat treatment of olive pulp expeller separated as far as possible from parts of the kernel	Crude protein Crude fibre

3.2 Olive oil production technologies

The main steps in olive oil production are the same, regardless of the equipment and process used[6]:

- Cleaning: the olive fruit is separated from stems, twigs, leaves and other impurities.
- Grinding: the cleaned olive fruit is grinded into a paste.
- Malaxing: mixing the olive paste in order to allow smaller oil droplets to combine into larger ones. During this process, the olive paste may be heated.
- Separation: the olive oil is separated from the vegetable water and solids through presses or centrifuges.

There are three main production methods for olive oil[7] which have an impact not only on the olive oil quality and production costs, but also on the olive pomace characteristics.

The traditional method is essentially the ancient way of producing olive oil. The grinding step is implemented through granite wheels. After malaxation, the olive pulp is spread over fibre mats or

[6] "Olive oil source – Extraction process" (www.oliveoilsource.com/page/extraction-process - last accessed on 26 March 2021)
[7] "Gruppo Pieralisi – Olives to the heart" (www.pieralisi.com/media/files/143_92_olives_tothe_heart.pdf last accessed on 26 March 2021)

filtration diaphragms and the olive oil is separated through the use of presses. The traditional method has several advantages: it is a simple process, requires minimal process water (only for washing the olives), produces a low-moisture olive pomace (similar to the three phase systems) and has a low power consumption. However, it requires a lot of manpower and the quality of the olive oil is influenced by the proper cleaning of the grindstones, which is not so easy. Currently, the traditional process is employed by only a minimum number of olive mills in the major EU olive oil producing countries.

The three-phase technology is the first variant of the continuous olive oil extraction methods. The distinct characteristic of the continuous methods is the use of a horizontal centrifuge system – the decanter – for the separation of the olive oil from the olive paste after the malaxation. Metal crushers are also used for the grinding step. The operation of the three-phase system requires that the olive paste is mixed with significant volumes of warm water upon entry into the decanter, which produces three distinct streams (hence the name): olive oil, an olive pomace with a moisture content of around 50 w-% and vegetable water for disposal.

The two-phase technology is the second main variant of the continuous olive oil extraction methods. In the two-phase process, the decanter is set to produce only two streams: olive oil and a “wet” olive pomace with a moisture content of around 70 w-%. The two-phase process is considered to result in a healthier, higher quality olive oil, retaining a larger amount of polyphenolic compounds that would have been lost in the vegetable water. The system is also frequently labelled as “ecological” since it practically eradicates the handling issue of the large volumes of olive mill wastewater generated by the three-phase process. The main disadvantage of the two-phase system is related with the issue of handling the wet olive pomace.

In Spain, the world’s leading olive oil producer, two-phase systems are estimated to cover around 90 % of the total olive oil production. In Greece, adoption of the two-phase system has been slower. SPEL estimates that around 60 % of the Greek olive oil production takes place with the two-phase system, with the remaining 40 % being three-phase. The uptake of the two-phase technology is estimated to be even higher in Crete and Peloponnese, the major centres of olive oil production in the country.

3.3 Olive pomace management

3.3.1 Extraction of crude olive pomace-oil

In the major olive oil producers of the EU – Spain, Italy, Greece and Portugal – the olive pomace, whether from two-phase or three-phase olive mills – is typically handled by secondary mills, known as **olive pomace mills**. The main purpose of the treatment is to recover the residual olive pomace oil in the pomace.

The first process step at olive pomace mills is the drying of the incoming olive pomace to a moisture level of around 10 w-%. Following this step, the dry olive pomace is treated with solvents, such as hexane, that are used to recover the residual oil in the form of crude olive-pomace oil, which can then be further refined in appropriate facilities. The solid residue of the process is known as exhausted olive cake and comprises of the olive fruit flesh, skin and any quantities of olive stones that have not been extracted in previous steps of the process.

Olive pomace mills self-consume large volumes of the exhausted olive cake they produce in order to produce hot flue gases for the drying of the incoming wet pomace and steam required for the crude olive pomace-oil extraction step.

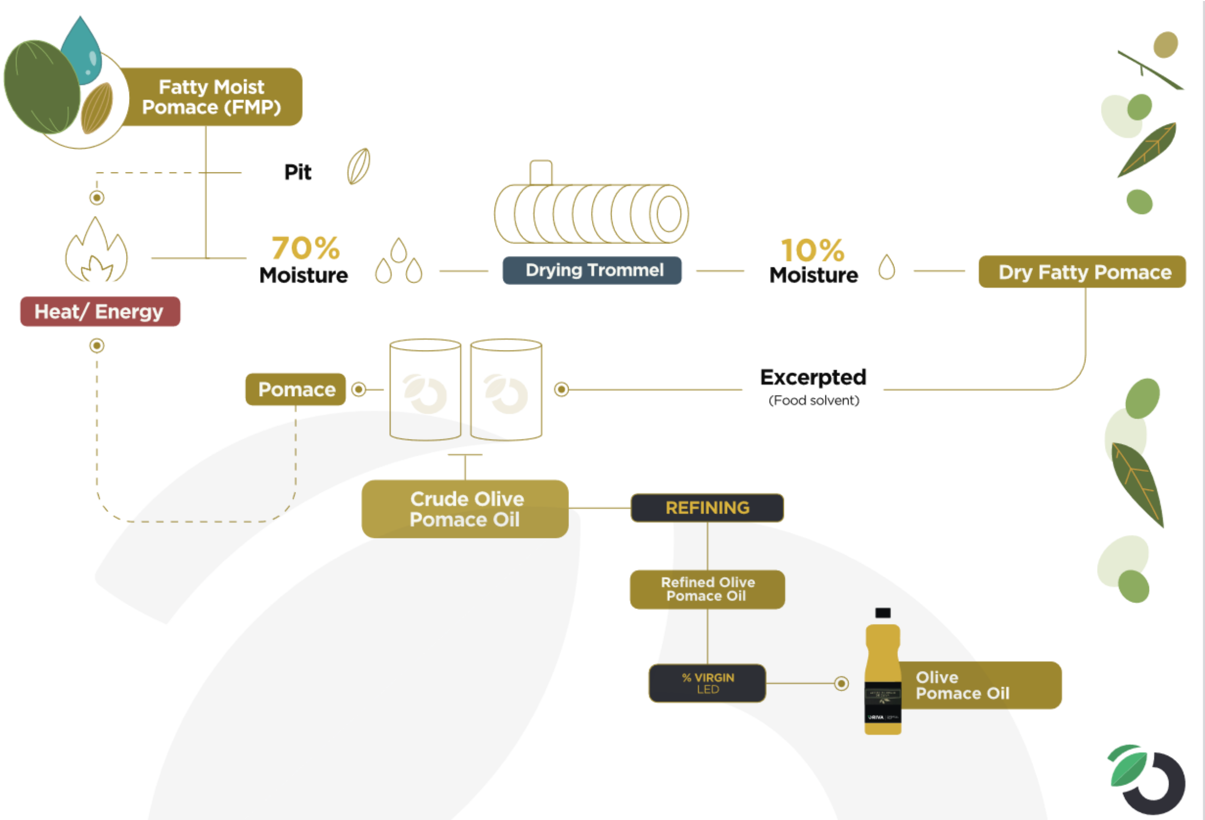

Figure 1: Overview of the olive pomace-oil production[8]

3.3.2 Anaerobic digestion of olive pomace

An alternative management practice for olive pomace is its treatment in anaerobic digesters for the production of biogas. In September 2020, Italian biogas technology provider inaugurated one of the first biogas plants in Europe fed exclusively with two-phase olive pomace from which the olive stones where previously extracted[9]. The plant, built for the Agrolio company, has an electrical capacity of 500 kWe and an equal thermal capacity. In Greece, the practice of using olive pomace as part of the feedstock mixture for some biogas plants has been confirmed through interviews.

3.3.3 Direct use of olive pomace on the soil

In Italy, Law 11 November 1996, n. 574 "New rules on the agronomic use of vegetation waters and discharges from oil mills"[10] allows for the direct application of both olive mill wastewater and olive pomace for agronomic use through controlled spreading on land used for agricultural purposes under

[8] "ORIVA – Olive Pomace Oil" (https://oriva.es/en/olive-pomace-oil/ - last accessed on 26 March 2021)

[9] "COMUNICATO STAMPA - Inaugurazione del primo impianto BTS Biogas alimentato con sansa di olive" (https://www.bts-biogas.com/fileadmin/user_upload/COMUNICATO_STAMPA_AGROLIO_BTS_Biogas_DEF.pdf - last accessed on 26 March 2021)

[10] Legge 11 novembre 1996, n. 574 "Nuove norme in materia di utilizzazione agronomica delle acque di vegetazione e di scarichi dei frantoi oleari" pubblicata nella Gazzetta Ufficiale n. 265 del 12 novembre 1996 (https://www.camera.it/parlam/leggi/96574l.htm - last accessed on 26 March 2021)

certain conditions and limitations. Although agronomic use of olive mill wastewater through controlled dispersion may be allowed in other EU members states – including Greece – the practice of direct use of olive pomace does not appear to take place elsewhere in the EU.

3.4 Exhausted olive cake, olive stones and olive pulp

The olive oil and olive pomace-oil processing leads to the formation of a solid biomass residue, known as **exhausted olive cake**. This material consists of the remaining biomass of the olive fruit, e.g. skin, flesh and the any stone that has not been extracted in previous processing steps.

On the other hand, **olive stones** refer to the recovered fraction of the olive fruit endocarp. There are different possibilities to separate the olive stones in the process[11]: from the olive paste at the olive mills before malaxation, from the olive pomace or from the exhausted olive cake. In the first two cases, olive stones are recovered through centrifugation and screening, while for the latter case it is typically suction and screening that is applied.

Both exhausted olive cake and olive stones can be used as solid biomass fuels, having low moisture contents and a high calorific value. However, their fuels properties are not similar due to their different composition. Olive stones have a lower content of ash and elements (e.g. sulphur, chlorine, nitrogen) that can create combustion issues such as slagging / fouling or increased emissions. For this reason, they are considered as a premium fuel, able to obtain higher market prices and can also be used in small-scale, domestic heating applications.

On the other hand, exhausted olive cake has a higher content of ash and "problematic" elements, meaning that its use for larger-scale, industrial applications is preferable and for which its low cost can make it a very competitive option. As mentioned previously, large quantities of exhausted olive cake are consumed by the olive pomace mills themselves to cover their own energy needs.

Both fuels have a high energy density, meaning that they can be effectively transported over long distances[12], even exported to third countries. Table 3 provides a short comparison of some key fuel properties of olive stones and exhausted olive cake.

Table 3: Comparison of olive stones and exhausted olive cake fuel properties[13]

Property	Unit	Olive stones		Exhausted olive cake	
		Typical value	Typical range	Typical value	Typical range
Moisture	w-% a.r.	≤ 12	4 – 20	14	9 – 16
Ash	w-% a.r.	≤ 0.7	0.3 – 1.5	7	5 – 11
Volatiles	w-% a.r.	82	80 – 85	65	45 – 80
NCV	MJ/kg a.r.	16.8	> 15	16.5	> 15
Chlorine	w-% a.r.	≤ 0.03	0.01 – 0.03	0.2	< 0.2
Sulphur	w-% a.r.	≤ 0.03	0.01 – 0.03	0.1	< 0.25

[11] Pattara C., Cappelletti G.M., Cichelli A. (2010) Recovery and use of olive stones: Commodity, environmental and economic assessment. Renewable and Sustainable Energy Reviews 14:1484-1489. https://doi.org/10.1016/j.rser.2010.01.018

[12] "ANEO – Biomasa" (https://www.aneorujo.es/biomasa/ - last accessed on 26 March 2021)

[13] Rodero P., Esteban L. Barro R. (2015) The olive oil industry - Main by-products and their characteristics as fuels.

Both exhausted olive cake and olive stones are included in the EN 14961-1[14] standard on solid biofuels fuel specifications and classes, which has now been superseded by EN ISO 17225-1[15]. Table 12 of EN ISO 17225-1 covers specifications for olive residues, the origin may come from one of the four categories of Table 1 of the standard, as summarized in the following table.

Table 4: Origin classification of olive residues used as solid biofuels according to ISO 17225-1

3. Fruit biomass	3.2 By-products and residues from food and fruit processing industry	3.2.1 Chemically untreated fruit residues	3.2.1.2 Stone/kernel fruits/fruit fibre
			3.2.1.4 Crude olive cake
		3.2.2 Chemically treated fruit residues	3.2.2.2 Stone/kernel fruits
			3.2.2.4 Exhausted olive cake

EN ISO 17225-1 also provides distinguishes between normative and informative properties of solid biofuels from olive residues, as follows[16]:

- Normative properties (shall be specified): Origin, Traded form, Dimensions (e.g. Diameter), Moisture, Ash, Additives, Net Calorific Value, Nitrogen
- Informative properties (voluntary): Amount of small fines, Bulk density, Chlorine, Sulfur, Ash melting temperature

The Spanish Association for Certification – UNE has adopted a quality standard for graded olive stones[17]. Based on this standard, it is also possible for an olive stone producer that meets the requirements to certify this product under the BIOmasud® certification scheme (www.biomasud.eu). BIOmasud® is a private fuel quality and sustainability certification system developed through two European projects[18]. The scheme – which also covers several other solid biofuels – is currently present in Spain, Portugal, Greece, Italy and Slovenia and has certified a small number of olive stone producers in Spain and Italy[19].

Both exhausted olive cake and olive stones contain a small amount of residual oil that was not possible to be recovered by the olive oil or olive pomace-oil extraction process. The oil content is not included as a normative or informative property in EN ISO 17225-1, but it included as a normative property in UNE 164003 and in the BIOmasud® scheme. Research has suggested that increased oil content can

[14] EN 14961-1:2010 Solid biofuels - Fuel specifications and classes - Part 1: General requirements
[15] EN ISO 17225-1:2014 Solid biofuels — Fuel specifications and classes — Part 1: General requirements
[16] ISO 17225-1:2020 (FDIS) ISO TC 238 Secretariat: SIS Solid biofuels — Fuel specifications and classes — Part 1: General requirements (www.aielenergia.it/public/documenti/576_ISO_FDIS_17225-1.pdf - last accessed on 26 March 2021)
[17] UNE 164003:2014 Biocombustibles sólidos Especificaciones y clases de biocombustibles Huesos de aceituna (www.une.org/encuentra-tu-norma/busca-tu-norma/norma?c=N0053717 – last accessed on 26 March 2021)
[18] BIOmasud financed with ERDF funds under the Interreg IV-B program and Biomasud Plus (www.biomasudplus.eu) funded by European Union's Horizon 2020 research and innovation program under grant agreement No 691763.
[19] As of March 2021, five companies are listed as certified olive stones producers by the scheme: https://biomasud.eu/en/companies-certified/

have a negative influence in combustion, leading to increased emissions; increased emissions of several pollutants were measured during combustion tests of olive stones with an oil content of 2 %w-dry basis at domestic appliances (boiler and stove)[20]. The negative influence of the oil content in combustion process has prompted some countries to impose national limits on the maximum oil content in such solid biofuels.

Finally, **olive pulp** is a substance that is obtained from the exhausted olive cake after screening and removal of the stones. Olive pulp is included the list of feed materials under Commission Regulation (EU) No 68/2013 (see Section 3.4 of this report) and can be used as a protein supplement for animal feeding[21].

3.5 Market situation in Greece

Global olive oil production reached 3,262,000 tons in the 2018/2019 campaign, a quantity tripled over the last 60 years[22]. Greece producers on average around 300,000 tons of olive oil per campaign and is the third largest producer in the world, after Spain – by far the world leader – and Italy. Olive oil is one of the most emblematic products of Greek agriculture, amounting to 9 % of the total production value of the sector for the 2011-2014 period and contributing to approximately 0.4% (750 million EUR) of the country GDP[23]. The table below presents the evolution of the Greek olive oil production in comparison with the world one and that of other EU Member States.

Table 5: Global and EU production of olive oil[24]

	Olive oil campaign season production data (x 1,000 tons)				
	2015/16	**2016/17**	**2017/18**	**2018/19 (1)**	**2019/20 (2)**
World	3,177	2,561	3,379	3,217	3,144
Spain	1,403	1,291	1,262	1,790	1,230
Italy	475	182	429	174	340
Greece	**320**	**195**	**346**	**185**	**300**
Portugal	109	69	135	100	125
Rest of EU	17	15	16	15	16
(1) Provision data (2) Prevision					

[20] Mediavilla I., Barro R., Borjabad E., Pena D., Fernandez M.J. (2020) Quality of olive stone as a fuel: Influence of oil content on combustion process. Renewable Energy 160 374-384. https://doi.org/10.1016/j.renene.2020.07.001

[21] "ANEO – Biomasa" (https://www.aneorujo.es/biomasa/ - last accessed on 26 March 2021)

[22] "International Olive Oil Council - World's olive oil production has tripled" (https://www.internationaloliveoil.org/worlds-olive-oil-production-has-tripled/ - last accessed on 26 March 2021)

[23] "National Bank of Greece – Olive Oil: Establishing the Greek Brand (Sectoral Report, May 2015)" (https://www.nbg.gr/greek/the-group/press-office/e-spot/reports/Documents/Olive%20Oil_2015.pdf – last accessed on 26 March 2021)

[24] International Olive Oil Council – Olive Oil Dashboard (www.internationaloliveoil.org/wp-content/uploads/2020/09/IOC-Olive-Oil-Dashboard-September-2020.html - last accessed on 26 March 2021)

3.5.1 Olive mills and olive pomace mills

The number of olive mills in Greece is on a declining trend. The structure of the olive mill sector in Greece is quite different compared to the Spanish and the Italian one, in particular:

- Greek olive mills have an average olive oil production capacity of 200-230 t/season of olive oil season compared with 120 t/season in Italy and 750 t/season in Spain.
- The two-phase system has emerged as the main technology in Greece. SPEL estimates that around 60 % of the olive oil production corresponds to two-phase systems, while 40 % remains with the three-phase system. The uptake of the two-phase system is believed to be even higher in the major olive oil production centre of Peloponnese. These number appear to be in agreement with other sources which estimate that of the circa 1,600 olive mills in Greece, 55 % operate with the two-phase system, 45 % with the three-phase system and 5 % with the traditional method[25]. In comparison, over 90 % of Spanish olive oil production is performed with the two-phase system. In Italy the traditional method is still employed by about 40 % of the olive mills, which are small, decentralized units operating also bottling plants, while the uptake of the two-phase system is minimal.

The number of olive pomace mills in Greece has mostly remained stable over the years, with around 35 plants operating during each season. According to SPEL, a typical olive pomace mill in Greece handles around 450 – 500 t/day of olive pomace. Most of the olive pomace mills are located in the major olive oil centres of Peloponnese and Crete. In mainland Greece, olive pomace mills also operate in Voiotia, Fthiotida, Etoloakarnania and Magnisia; plants also operate in larger islands with significant olive oil production: Lesvos, Rhodes and Corfu. A non-exhaustive list of olive pomace mills in Greece is presented in the following table.

Table 6: Olive pomace mills in Greece (non-exhaustive list)

Company name	Plant(s) location (Regional Unit)	Website
ABEA	Chania	www.abea.gr
AGROTIKI SINETAIRISTIKI RETHIMNOU S.A. (A.S.E.A.R.)	Rethimno	www.asear.gr
Androulakis Pavlos Koinonia Klironomwn	Irakleio	n/a
CHATZELIS K. S.A.	Lakonia x 2, Messinia x1	www.chatzelisgroup.gr
EAS Lakonias	Lakonia	www.easlakonia.gr
Elaiourgia Argonafplias S.A.	Argolida	www.elargo.gr
Elaiourgia Magnisias S.A.	Magnisia	www.elargo.gr
Elaiourgiki Gytheiou AEBE	Lakonia	n/a
Elaiourgiki Voiotias	Voiotia	www.viotiaol.gr
Eleourgia Aigaiou	Lesvos	www.pyrina.gr
Eleourgia Nikolopoulos S.A.	Ilia	n/a
Eleourgia Prevezis	Preveza	www.eleourgiaprevezis.gr

[25] Mourtzanos A. (2020) The transition from the three-phase to the two-phase olive oil production system and the implications in the olive oil and olive pomace-oil industry in Greece. Diploma thesis – in Greek. https://dspace.lib.ntua.gr/xmlui/handle/123456789/52403

Company name	Plant(s) location (Regional Unit)	Website
Eleourgikes Epixeiriseis Patrwn S.A.	Achaia	n/a
Eleourgiki Ilias S.A.	Ilia	www.eleourgiki-ilias.gr
Eleourgiki Thessalias	Larisa	n/a
ELKE – Eleourgiki Kentrikis Ellados	Fthiotida	n/a
ELSAP S.A.	Argolida x1, Etoloakarnania x1, Corfu x 1	www.elsapsa.gr
Kentouri K. Yioi S.A.	Samos	n/a
MESSINIAKI	Messinia	www.messiniaki.gr
Oichalia Epeksergasia Viomazas Ltd.	Messinia	n/a
PYRINAS S.A.	Messinia	n/a
Pyrinelourgeio Almpantaki Ierapetras S.A.	Lasithi	www.greekpomace.gr
Pyrinelourgia Notias Kritis S.A.	Irakleio	n/a
Pyrinelourgio Rodou	Rhodes	n/a
VIOEL S.A.	Chania	n/a
Viomichania Zootrofon Siteias Georgias Vas. Plakakis S.A.	Lasithi	http://zootrofes-plakakis.blogspot.com/

Table 7 present statistical data on the number of olive mills and olive pomace mills operating in Greece as well as the production volume of olive pomace and exhausted olive cake. It is clear that the olive pomace production variates depending on the olive oil production volume; with it, the exhausted olive cake production also varies.

Table 7: Number of olive mills and olive pomace mills, production of olive pomace and exhausted olive pomace in Greece[26]

Property	Unit	Year				
		2015	2016	2017	2018	2019
Olive mills in operation	#	1,844	1,700	1,694	1,630	1,642
Olive pomace mills in operation	#	35	31	32	36	33
Olive pomace production	t	590,645	431,784	697,945	518,194	697,370
Exhausted olive cake production	t	298,172	222,366	353,114	259,064	362,055

Most of the olive pomace mills in Greece were initially designed to handle the drier three-phase olive pomace. The transition of the olive mills to the two-phase system has created issues for the olive pomace mills, since their facilities are not always equipped to handle large volumes of the wetter two-phase olive pomace. In order to solve this issue, a typically strategy employed by the olive pomace mills is the mixing of the incoming two-phase olive pomace with three-phase pomace, dry olive

[26] Source: statistical data provided by the Energy Policy and Planning Department of the Centre for Renewable Energy Sources & Saving (CRES) – email communication of 25 February 2021

pomace or - more rarely - exhausted olive cake; in order to bring the moisture content of the material to be dried in a more manageable level for them.

3.5.2 Olive pomace market

The market prices for the three-phase olive pomace and the two-phase olive pomace are also different, reflecting both the handling difficulties of the latter as well as its higher moisture content. Olive pomace prices exhibit seasonal fluctuations depending on crude olive pomace-oil price.

In the last five years, olive mills have claimed market prices ranging between 15 – 45 €/t for three-phase olive pomace. The transportation costs is usually around 7 €/t and paid by the olive mills themselves. Therefore, the revenue for the olive mills from the sale of three-phase olive pomace has been between 8 – 37 €/t.

On the contrary, the two-phase olive pomace in the last five years had a market price between 9 – 25 €/t, even dropping down to 7 €/t recently. Considering that the transportation cost is still paid by the olive mills, it is apparent that the two-phase olive pomace, especially when the crude olive pomace-oil price is very low, does not generate any significant revenues for the olive mills.

The low market prices of olive oil and olive pomace-oil in recent years tended to compress down the prices; however, increasing trends have been observed lately.

The expansion of the biogas plants in Greece – especially in the Northern part of the country – has created new possibilities for olive pomace. Two-phase olive pomace in particular has a high organic load and can be a very potent substrate for biogas production, provided it can be taken up by the anaerobic digesting unit. Therefore, some biogas plants in Greece can afford to pay the transportation costs of two-phase or three-phase olive pomace from adjacent olive mills, since they can recover the costs through the feed-in tariff or feed-in premium they receive for their power production. Biogas plants may handle as well olive mill wastewater streams from three-phase olive mils, although the organic load – and therefore the biogas yield – of such streams is much lower.

3.5.3 Exhausted olive cake and olive stones market

Olive pomace mills consume for their own needs (heat for olive pomace drying, steam production for extraction) large volumes of the exhausted olive cake they produce. Large amounts of exhausted olive cake remain available for the market however and find their main use as a solid biomass fuel. SPEL estimates that in a “typical” olive oil year, e.g. 250,000 tons of olive oil production, the exhausted olive cake quantities that remain available for the market are around 135,000 tons.

Beyond self-consumption at the olive pomace mills, exhausted olive cake is used in various market segments in Greece, such as:

- <u>Residential heating</u>. A survey performed by ELSTAT for the heating period 2011 – 2012 reports that “olive cake” covered 0.4 % of the thermal energy consumption of Greek households or around 2.34 % of the total biomass consumption for space heating in the residential sector. The use of exhausted olive cake for residential heating takes place almost exclusively in rural and semi-rural areas[27], since the strong odour of the material is likely to cause complaints in more densely populated areas.

- Agricultural space-heating applications. The low cost of exhausted olive cake makes it a very competitive fuel for applications that have high thermal energy consumptions to maintain space heating over a large area, such greenhouses and animal farms.
- Olive mills. Exhausted olive cake is used by the olive mills to produce hot water used in various process steps (e.g. malaxation) and frequently for space-heating.
- Industrial applications. Exhausted olive cake can be used as a fuel in various industrial processes, e.g. for the production of lime, processing of minerals, etc.
- Power production. Eectricity production from solid biomass is still in early stages of development. However, the power plant of VIOPAR Energy S.A. (www.viopar-energy.gr), the largest solid biomass power plant in Greece with an installed capacity of 5 MWe, is licensed to use exhausted olive cake, among other biomass fuel fractions[28].

Separation of olive stones by olive mills (e.g. from the olive paste or olive pomace) in Greece is quite rare, since the practice further reduces the value of the olive pomace obtained by the olive pomace mills. For technical reasons, olive pomace mills in Greece rarely separate the olive stones from the olive pomace. However, several olive pomace mills may process (e.g. through aerodynamic separation) the exhausted olive cake to obtain different fractions of materials. The fraction containing most of the olive stones may be marketed as "woody" olive cake or upgraded "pirinoksilo", while the remaining fraction containing most of the pulp may be marketed as a solid biofuel of lower quality or used for the production of olive pulp (see next section).

The market prices for exhausted olive cake exhibit seasonal fluctuations depending on two main factors: level of olive oil production (hence of exhausted olive cake) and winter weather conditions. Typical prices are in the range of 50 – 80 €/t. The price of olive stones is around 150 €/t, reflecting its higher fuel quality[29]. Prices are generally higher in islands (e.g. Crete, Lesvos) where access to alternative, low-cost biomass fuels is more restricted / expensive.

3.5.4 Olive pulp market

No statistical data on the olive pulp market in Greece are available. However, olive pulp products for animal feed are available by some companies that are also active in the olive pomace processing sector or sourcing exhausted olive cake from olive pomace mills. For example, Cretan Mills S.A. process exhausted olive cake to produce two distinct products:

[27] Hellenic Statistical Authority (2013). Development of detailed statistics on Energy consumption in households-2011/2012: Quality report. Grant Agreement Eurostat n° 30304.2010.002-2010.373. (https://ec.europa.eu/eurostat/cros/system/files/SECH_final_report_Greece.pdf - last accessed on 26 March 2021)

[28] Tsovilis G., Arvanitis T. (2020) Biopower – VIOPAR S.A. – the largest biomass power plant in Greece. Presentation at Biomass Day 2020 event. (http://bioenergynews.gr/wp-content/uploads/2020/12/tsovilis_arvanitis.pdf - last accessed on 26 March 2021)

[29] Karampinis M., Kougioumtzis M.A. Kanaveli I.P. Stavropoulou C., Papasideri C. (2020) AgroBioHeat Deliverable 5.1: National and European framework conditions - Part 6: National framework conditions – Greece. (https://agrobioheat.eu/wp-content/uploads/2020/10/AgroBioHeat_D5.1_Part-6_Greece-framework-conditions.pdf - last accessed on 26 March 2021)

- "Olive biomass"[30], a solid biomass fuels containing the separated "woody" part of the exhausted olive cake, e.g. the olive stones.
- Oliveoleic[31], an animal feed supplement from the "depitted" part of the exhausted olive cake.

ASEAR S.A. in Crete operates an olive pomace mill as well as a animal feed processing plant. The exhausted olive cake it produces undergoes a similar separation into the "woody" and "pulp" part and the latter is used as a material for animal feed production[32].

3.6 Legal framework in Greece

3.6.1 Legal framework for olive pomace

JMD Φ.15/4187/266/11.4.2012[33] establishes Standard Environmental Commitments for various economic activities within its scope: general commitments, health and safety aspects, noise, gaseous wastes, liquid wastes, solid wastes and special commitments.

Olive mills belong to the economic activity Code 10.4 "Production of vegetable and animal oils and fats". Among others commitments, JMD Φ.15/4187/266/11.4.2012 specifies that operations under this economy activity should comply with requirement Z8 for solid wastes:

- *Olive pomace should be made available to olive pomace mills.*

JMD 127402/1487/Φ15/2016[34] amends the aforementioned JMD, modifying – among others – requirement Z8 as follows:

- *Olive pomace should be made available to olive pomace mills or transferred for further treatment to legally operating and appropriately licensed bodies, according to legislative requirements.*

This amendment opens the door for processing of olive pomace by other economic actors, for example biogas power plants, provided they are legally licensed to handle this stream.

The inclusion of handling requirements for olive pomace under the "solid wastes" category of both aforementioned JMDs has created uncertainties as to the legal status of olive pomace and caused issues with the environmental licenses of both olive mills and olive pomace mills. A specific issue that appear was whether olive pomace should be declared in the Digital Waste Registry (DWR -

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30 "Cretan Mills – Viomaza Elias" (www.mills.gr/products/viomaza-elias/ - last accessed on 26 March 2021)
31 "Cretan Mills – Oliveoleic product specifications" (www.mills.gr/wp-content/uploads/2018/11/Olive-pulp-έντυπο-2020.pdf - last accessed on 26 March 2021)
32 "ASEAR – Pyrinelourgeio" (www.asear.gr/el/pyrinas.php - last accessed on 26 March 2021)
33 Κ.Υ.Α. Φ.15/4187/266/11.4.2012 (ΦΕΚ 1275/Β` 11.4.2012) Καθορισμός πρότυπων περιβαλλοντικών δεσμεύσεων (ΠΠΔ), κατά κλάδο δραστηριότητας, στην άδεια εγκατάστασης- λειτουργίας, για τις δραστηριότητες που εμπίπτουν στο πεδίο εφαρμογής του Ν. 3982/2011 και κατατάσσονται στη Β κατηγορία του άρθρου 1 του Ν. 4014/2011
34 Υ.Α. οικ. 127402/1487/Φ15/2016 (ΦΕΚ 3924/Β` 7.12.2016) Τροποποίηση της υπ' αρ. Φ. 15/4187/266/2012 (Β΄ 1275) κοινής απόφασης των Υπουργών Ανάπτυξης, Ανταγωνιστικότητας και Ναυτιλίας και Περιβάλλοντος, Ενέργειας και Κλιματικής Αλλαγής «Καθορισμός Πρότυπων Περιβαλλοντικών Δεσμεύσεων (ΠΠΔ), κατά κλάδο δραστηριότητας στην Άδεια Εγκατάστασης-Λειτουργίας, για τις δραστηριότητες που εμπίπτουν στο πεδίο εφαρμογής του Ν. 3982/2011 και κατατάσσονται στην Β κατηγορία του Άρθρου 1 του Ν. 4014/2011»

https://wrm.ypeka.gr/). A communication from YPEN[35] clarified that the declaration of olive pomace as a by-product is investigated and until the issue is resolved the following actions should be taken:

- Olive mills and olive pomace mills should be registered in the Digital Waste Registry, since they are subject to environmental license procedures.
- Declaration of olive pomace is not mandatory; facilities that have completed their Waste Report need not take any action.

JMD 127402/1487/Φ15/2016 has also provided for the first time the possibility for olive mills to apply olive mill wastewater on agricultural soils, under certain conditions. The conditions for this application were further simplified under JMD 135207/1801/2017[36]. In both cases, the direct use of olive pomace on agricultural soils is not foreseen.

3.6.2 Legal framework for exhausted olive cake

MD 189533/2011[37] establishes the legal framework for the operation of the following types of installations:

a. Central heating installations for buildings of the residential and service sectors as well as space heating installations for industrial and commercial units, provided they are used exclusively for this purpose.
b. Installations for the production of hot water or steam at buildings of hotels, hospitals and other similar activities, swimming pools, spas and dry cleaning facilities.

Solid biofuels falling within the scope of standard EN 14961−1 are considered as allowable fuels for the operation of the aforementioned facilities. New installations using solid biomass fuels are required to meet the efficiency and emission limit requirements of standard EN 303-5[38]. A national NOx emission limit is also introduced.

MD 198/2013[39] establishes requirements for solid biomass fuels intended for non-industrial use. Within the scope of this decision are installations covered by MD 189533/2011 as well as local heating applications (e.g. fireplaces, stoves). The Decision establishes requirements for sampling, fuel classes and testing standards and quality assurance, referencing the relevant EN standards that were developed by CEN/TC 335.

More specifically, MD 198/2013 provides definitions for “crude olive cake” (equivalent to olive pomace) and “exhausted olive cake” and establishes the following requirement, in addition to those of Table B.9 - Typical values for olive and grape cake of standard EN 14961-1:

- *The oil content of crude olive cake and exhausted olive pomace should not exceed 2 % w- on a dry basis. The oil content should be determined with the method established by Commission*

[35] https://wrm.ypeka.gr/library-article/13 (last accessed on 26 March 2021)
[36] Υ.Α. οικ. 135207/1801/2017 (ΦΕΚ 4333/Β` 12.12.2017) Τροποποίηση της υπ’ αριθμ. Φ.15/4187/266/2012 (Β΄ 1275) κοινής απόφασης των Υπουργών Ανάπτυξης, Ανταγωνιστικότητας και Ναυτιλίας και Περιβάλλοντος, Ενέργειας και Κλιματικής Αλλαγής
[37] Υ.Α. Αριθ. πρωτ. οικ.: 189533/2011 (ΦΕΚ 2654/Β` 9.11.2011) Ρύθμιση θεμάτων σχετικών με τη λειτουργία των σταθερών εστιών καύσης για τη θέρμανσης κτιρίων και νερού
[38] EN 303-5:2012 Heating boilers - Part 5: Heating boilers for solid fuels, manually and automatically stoked, nominal heat output of up to 500 kW - Terminology, requirements, testing and marking
[39] Υ.Α, 198/2013 - ΦΕΚ 2499/Β/4-10-2013 Καύσιμα στερεής βιομάζας για μη βιομηχανική χρήση -Απαιτήσεις και Μέθοδοι Δοκιμών

Regulation (EEC) No 2568/91 of 11 July 1991 on the characteristics of olive oil and olive-residue oil and on the relevant methods of analysis (Annex XV-Oil content of olive residue).

No specific requirements for the use of exhausted olive cake as a solid biofuel for industrial applications are noted in the Greek legislation.

3.7 Olive oil and olive pomace-oil production residues: by-products or wastes?

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives was implemented in Greece through Law 4042/2012. Among others, Law 4042/2012 provides a legal definition of waste and establishes the main legal framework for waste management and obligations of waste producers.

Article 12 of Law 4042/2012 transposes Article 5 of Directive 2008/98 and introduces the definition of by-products, as a separate legal category from waste. Specifically, a by-product is defined as a substance or object, resulting from a production process, the primary aim of which is not the production of that item and which is not characterized as a “waste” only if four conditions are met:

a. Further use of the substance or object is certain.
b. The substance or object can be used directly without any further processing other than normal industrial practice.
c. The substance or object is produced as an integral part of a production process.
d. Further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

The importance of the correct classification of by-products in order to avoid environmental damage or unnecessary costs for business is recognized by the European Waste Framework Directive[40].

The following figure presents a decision tree which can be used to determinate whether a material is a product, a by-product or a waste.

[40] “European Commission – Waste Framework Directive“ (https://ec.europa.eu/environment/topics/waste-and-recycling/waste-framework-directive_en#ecl-inpage-631 – last accessed on 26 March 2021)

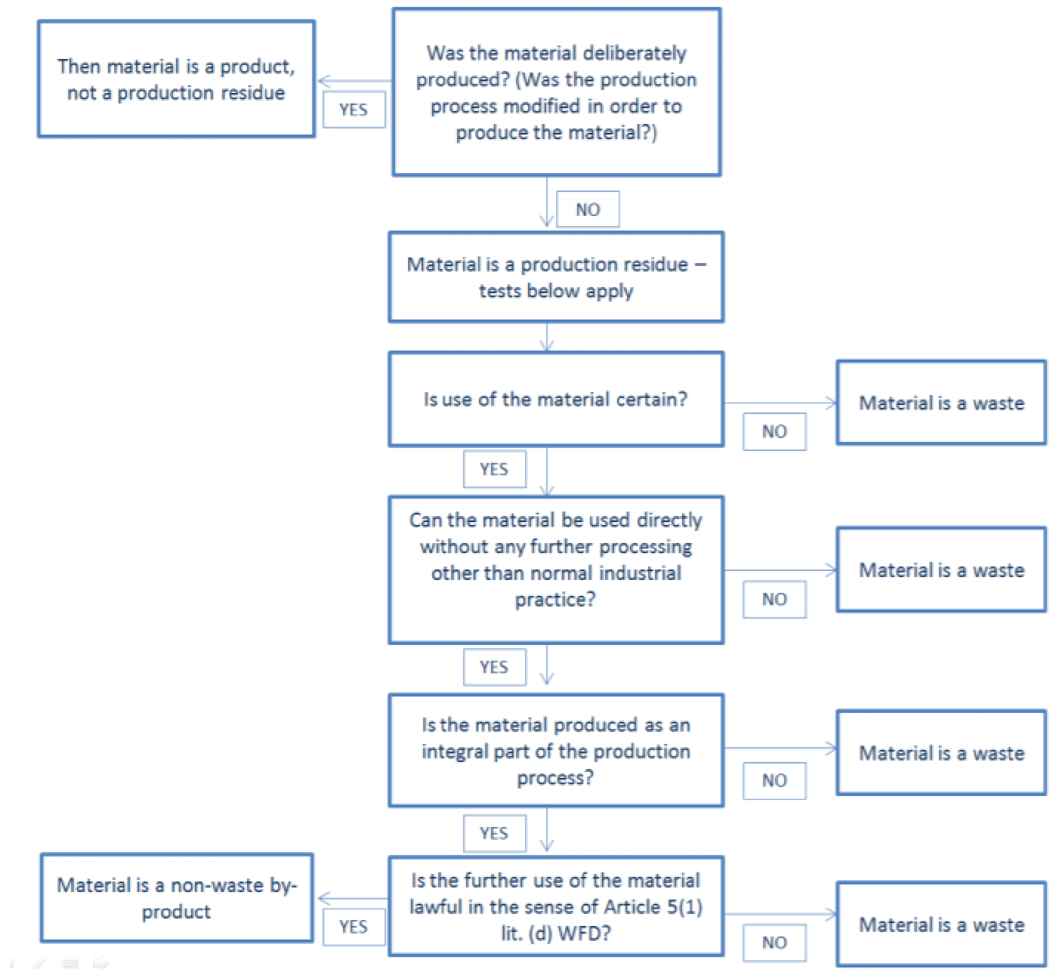

Figure 2: Decision tree for determining whether a material is a by-product[41]

Recently, the issue of the categorization of olive pomace as a by-product has been raised in Spain. Up until now, the different Autonomous Communities of Spain followed different approaches on the issue, with those having more familiarity with olive oil production treating it as a by-product, while some others have considered it as waste. In order to provide a unified approach, the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO) launched in late October 2020 a public consultation on a draft Ministerial Order to categorize olive pomace as a by-product throughout the Spanish territory[42]. At the time of writing, the final text of the Ministerial Order has not been published.

[41] European Commission - Guidelines on the interpretation of key provisions of Directive 2008/98/EC on waste (Not legally binding) (http://waste-prevention.gr/waste/wp-content/uploads/2015/10/2012_Guidance%20interpretation%20Directive%2098-2008-EC_EN.pdf - last accessed on 26 March 2021)

[42] (FIN DE PLAZO 2020-11-30) Proyecto de Orden Ministerial por la que se determina cuándo los orujos grasos procedentes de almazara y destinados a la extracción de aceite de orujo de oliva crudo se consideran subproductos, con arreglo a la Ley 22/2011, de 28 de julio, de residuos y suelos contaminados (https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/participacion-publica/PP-Residuos-2020-Proyecto-Orden-determina-cuando-orujos-grasos-extraccion-aceite-orujo-subproductos.aspx - last accessed on 26 March 2021)

Considering these set of criteria, the characterization of four streams - olive pomace, exhausted olive cake, olive stones, olive pulp – from the overall olive oil / olive pomace-oil value chain as by-products is assessed under the Greek framework conditions.

3.7.1 Olive pomace

For the possibility of characterizing olive pomace as a by-product, the main value chain for this stream in Greece is considered: transformation of olive pomace into crude olive pomace-oil at olive pomace mills.

Considering the decision tree of Figure 2, the first step is to establish whether olive pomace can be considered as a production residue or a product. From the discussion so far, it is clear that olive pomace is a production residue of the olive oil production process. The next step is to evaluate whether olive pomace meets the criteria for its characterization as a by-product.

The results of the evaluation are presented in Table 8, from which it is clear **that olive pomace meets all the criteria to be characterized as a by-product for the purposes of its use as a feedstock for crude olive pomace-oil extraction**. This assessment follows the reasoning of draft Ministerial Decision for the characterization of olive pomace as a by-product in Spain. A draft proposal for a JMD declaring olive pomace as a by-product, based on the Spanish example, is briefly presented in Section 6.1 of this report.

Table 8: By-product evaluation for olive pomace

Criterion	Evaluation
a. Further use of the substance or object is certain	Olive pomace mills are the main destination of olive pomace in Greece. Transfer of olive pomace to the olive pomace mills or other suitable management bodies is foreseen by the Standard Environmental Commitments (JMD 127402/1487/Φ15/2016) Olive pomace mills will accept the material and use it to produce olive pomace oil provided it has not been contaminated by foreign substances. Olive pomace has a variable market price, depending on the moisture content.
b. The substance or object can be used directly without any further processing other than normal industrial practice	Olive pomace is transferred from the olive mills to the olive pomace mills in the condition at which it was obtained. No processing of the material takes place, with two exceptions that can be considered as normal industrial practices: • Separation of the olive stones from the olive pomace; at the moment, this practice is implemented only by a small number of olive mills in Greece. • Drying of the olive pomace; at the moment, this is a standard industrial practice that takes place at the olive pomace mills. However, this process can be implemented by intermediate actors that can perform an initial drying of the olive pomace before it is transported to the olive pomace mills as a way to minimize transportation costs.
c. The substance or object is produced as an integral part of a production process	Olive pomace is produced as an integral part of the olive oil production process, after the malaxation of the olive paste and by separation of the olive oil through presses or centrifugation.

Criterion	Evaluation
d. Further use is lawful	Olive pomace is used by olive pomace mills to produce crude olive-pomace oil, an agricultural product explicitly mentioned in Regulation (EC) 1234/2007 and governed by the agro-food legislation.

Regarding alternative management methods for olive pomace, the following observations can be made for Greece:

- The use of olive pomace as a feedstock for biogas production in anaerobic digestion plants can be technically feasible. The economic feasibility of this route relies on the subsidized price for the electricity generated by biogas plants. The practice has been adopted in certain areas of Greece, especially in Macedonia and Thrace, where there are several local biogas plants in closer vicinity to olive mills compared to olive pomace mills. This practice valorises the energy content of the olive pomace; however, recovery of the residual oil does not take place. The draft JMD proposal does not exclude a priori this pathway, the adoption of which anyway requires that the biogas plant is legally licensed to handle olive pomace. This pathway may also be considered relevant in cases when the olive pomace is contaminated, or when transportation to olive pomace mills does not make economic sense. However, for the purposes of treatment in anaerobic digestion plants, olive pomace should be considered as a "waste" material, with all the legal implications this entails (e.g. declaration on the Digital Waste Registry). In such a case, olive pomace should be declared under Code 02 03 01 "sludges from washing, cleaning, peeling, centrifuging and separation" of the European Waste Code (EWC).
- Direct use of olive pomace on the soil as a fertilizer is not allowed in Greece; JMD 135207/1801 allows this possibility only for the olive mill wastewater under certain conditions. Therefore, this pathway is not considered further.

3.7.2 Exhausted olive cake

For the possibility of characterizing exhausted olive cake ("pirinoksilo) as a by-product, the main value chain for this stream in Greece is considered: its use as a solid biomass fuel for energy production.

Considering the decision tree of Figure 2, the first step is to establish whether exhausted olive cake can be considered as a production residue or a product. From the discussion so far, it is clear that <u>exhausted olive cake is a production residue of the crude olive pomace-oil production process</u>. The next step is to evaluate whether olive pomace meets the criteria for its characterization as a by-product.

The results of the evaluation are presented in the following table, from which it is clear **that exhausted olive cake meets all the criteria to be characterized as a by-product for the purposes of its use as a solid biomass fuel**. This is included in the draft proposal for the JMD on olive oil by-products.

Table 9: By-product evaluation for exhausted olive cake

Criterion	Evaluation
a. Further use of the substance or object is certain	Significant volumes of exhausted olive cake are self-consumed by the olive pomace mills for their own production purposes (drying incoming olive pomace, steam production for pomace oil extraction). Remaining quantities are made available for the market and are purchased for various energetic end-uses: from space heating (domestic, greenhouses), to process heat and power production.
b. The substance or object can be used directly without any further processing other than normal industrial practice	Exhausted olive cake has a low moisture content upon production (around 15 w-%) and can be used as a solid biomass fuel directly. Exhausted olive cake may be further dried if needed, sieved in order to separate it into fractions of variable particle size, separated into different fractions (e.g. aerodynamic separation of the olive stones) or even pelletized. All these are considered as normal industrial practices for solid biomass fuels.
c. The substance or object is produced as an integral part of a production process	Exhausted olive cake is produced as an integral part of the olive pomace-oil production process, being the solid residue that remains after the incoming olive pomace has been dried and the residual oil extracted.
d. Further use is lawful	Use of exhausted olive cake for energy production is lawful. Exhausted olive cake is a solid biomass fuel covered by standard EN 14961−1. Solid biomass fuels included in the standard are allowed to be used for stationary combustion applications for space heating and warm water production falling under MD 189533/2011. Requirements for non-industrial use is regulated by MD 198/2013. No specific requirements for industrial use are noted; however the use of exhausted olive cake for energy production is included in the Decisions on the Approval of Environmental Terms of industrial facilities (e.g. the 4.99 MWe power plant of Viopar Energy at Volos).

3.7.3 Olive stones

Considering the decision tree of Figure 2, we propose that olive stones should be considered as a product, since they are a material that is deliberately produced in a number of different ways: a) separated from the olive paste, b) separated from the olive pomace, c) separated from the exhausted olive cake.

Olive stones are mainly intended to be used as a high-quality solid biomass fuels; use in such applications is lawful under MD 189533/2011 and MD 198/2013. For consistency purposes, it is proposed that the same upper limit in the olive oil content of olive stones as with olive pomace and exhausted olive cake is adopted.

It is noted that currently production of olive stones in Greece is relatively low compared to Spain, since the separation step is implemented only by a small number of olive mills and olive pomace mills. However, the situation may change in the future, as stricter air quality laws are enforced and solid biomass fuels have to achieve higher quality standards in order to meet emissions limits from their combustion even at small-scale installations.

3.7.4 Olive pulp

The raw material for production of olive pulp is generated from exhausted olive cake after the partial separation of olive stones. Therefore, it can be considered as a production residue from an exhausted olive cake upgrading process that aims to produce an upgraded solid biofuel, e.g. olive stones.

Olive pulp can be used as either a solid biofuel or for animal feed. We consider that the first usage is already covered by the requirements for exhausted olive cake. The following table presents the results of the by-product evaluation, from which it is clear **that olive pulp meets all the criteria to be characterized as a by-product for the purposes of its use as animal feed**. This is included in the draft proposal for the JMD on olive oil by-products.

Table 10: By-product evaluation for olive pulp

Criterion	Evaluation
a. Further use of the substance or object is certain	If separated from the exhausted olive cake, olive pulp can be used as an animal feed – or can be used as a solid biofuel (essentially labelled as exhausted olive cake).
b. The substance or object can be used directly without any further processing other than normal industrial practice	Olive pulp can be used as animal feed without any further processing beyond normal industrial practices, e.g. sieving, pelletizing, etc.
c. The substance or object is produced as an integral part of a production process	Olive pulp is produced as an integral part of an upgrading process that uses exhausted olive cake as feedstock and aims to produce an upgraded solid biofuel, e.g. olive stones.
d. Further use is lawful	Olive pulp is included in the list of feed materials of Commission Regulation (EU) No 68/2013 of 16 January 2013 on the Catalogue of feed materials; therefore further use for animal feeding is lawful.

4. Cheese production residues

Decision 97/80/EC[43] defines whey as a "by-product obtained during the manufacture of cheese or casein". In particular, following the mixing of milk with the starter culture of bacteria and enzymes that promote the casein coagulation of the cheese production process, cheese curd is formed. From the curd, around 10 % represents the cheese yield, while the other 90 % is cheese whey[44]; the exact figures vary depending on the cheese production process as well as on the milk origin.

The volume of cheese whey generated by the cheese production globally are enormous, estimated to be over 10 billion tons per year – the EU, being the world's largest producer of cheese is estimated contribute around 40 % of this figure[45]. Considering that out of the 156.9 million tonnes of whole milk available to the EU dairy sector in 2017, 37 % was used to produce cheese[46], a simplified estimation of cheese whey production would exceed 50 million tons per year. In dry matter, cheese whey production in 2018 was estimated to be 4.15 million tons[47]. The very high organic content of cheese whey can cause tremendous environmental damage if released in the environment without further processing. On the other hand, they represent a huge opportunity for bioenergy and biochemical production[48].

Decades ago, cheese whey was treated as a waste product, disposed along with the wastewater from cheese production units, often with limited to no pre-treatment and leading to significant environmental issues due to its high organic content. However, with the realization that the protein content of cheese whey is quite high, its use for the production of white cheese products or its valorisation as an animal feed started. Nowadays, cheese whey also finds use as a supplement in food and pharmaceutical products, raw material for protein extraction or as a substrate for biogas production through anaerobic digestion.

4.1 Definitions

The term "cheese whey" is often used in public discourse, legislation, and even in scientific literature to describe all by-products of the cheese production process with a high organic content. However, there are quite significant differences in different residual streams depending on how they were

[43] 97/80/EC: Commission Decision of 18 December 1996 laying down provisions for the implementation of Council Directive 96/16/EC on statistical surveys of milk and milk products (Text with EEA relevance) (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A31997D0080 – last accessed on 26 March 2021)

[44] Valta K., Kosanovic T., Malamis D., Moustakas K., Loizidou M. (2015) Overview of water usage and wastewater management in the food and beverage industry, Desalination. Water. Treat. 53 3335–3347, doi:10.1080/19443994.2014.934100.

[45] Carvalho F., Prazeres A.R., Rivas J. (2013) Cheese whey wastewater: characterization and treatment. Sci Total Environ 445–446:385–396. https://doi.org/10.1016/j.scitotenv.2012.12.038

[46] "Eurostat - 37 % of EU milk used to make cheese in 2017" (https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190314-1 - last accessed on 26 March 2021)

[47] "European Whey Processors Association – Economic Report 2020" (https://ewpa.euromilk.org/fileadmin/user_upload/Public_Documents/EWPA/Economic_Report_2019-V6-WEB-_EWPA_.pdf - last accessed on 26 March 2021)

[48] Ahmad T., Aadil R.M., Ahmed H., ur Rahman U., Soares B.C.V., Souza S.L.Q., Pimentel T.C., Scudino H., Guimaraes J.T., Esmerino E.A., Freitas M.Q., Almada R.B., Vendramel S.M.R., Silva M.C., Cruz A.G. (2019) Treatment and utilization of dairy industrial waste: a review. Trends Food Sci. Technol. 88, 361–372. https://doi.org/10.1016/j.tifs.2019.04.003

processed and to what extend the various proteins and other useful ingredients originating from the milk are separated and exploited. In order to avoid confusion, we propose the following terms for the purposes of this study:

Cheese whey: the residue that remains from milk after production of cheese or casein.

Whey cheeses: dairy products made from primary cheese whey.

Secondary cheese whey: the residue that remains after production of whey cheeses from cheese whey.

Cheese whey wastewater: liquid effluents mainly derived from the cleaning and washing activities (e.g. of production equipment, plant floor, milk transport vehicles) in a cheese production unit.

The following table presents the Greek translation of these terms – some common colloquial expressions are also provided.

Table 11: Terms used for various residual streams and products from cheese production

English	Greek
Cheese whey	Τυρόγαλα
Whey cheeses	Τυριά τυρογάλακτος
Secondary cheese whey	Δευτερογενές τυρόγαλα Απόγαλα Ορός γάλακτος Ορός λακτόζης Βρασμένο τυρόγαλα
Cheese whey wastewater	Υγρά απόβλητα τυροκομείου

4.2 Production and main properties of cheese production residues

There are many variations of the cheese production process, resulting in a large number of cheese qualities; the same cheese production unit may actually produce a variety of different cheese products. However, the main process steps are the same. Milk is mixed with a starter culture of bacteria and the rennet enzyme. This enhances the coagulation of the main milk protein that is retained by the cheese, casein. After the formation of the curd that contains milk solids and fats, the liquid cheese whey is separated and drained. The curd itself undergoes various process steps: salting, pressing, curing, and, finally, packaging as cheese[49].

Different rules-of-thumb indicate the volume of cheese whey production. A typical value quoted is that cheese whey represents 90 % of the cheese curd, with cheese being the remaining 10 %. The cheese whey yield depends on the type of milk used, type of cheese produced and process employed.

Cheese whey retains around 55 % of the various natural constituents of the milk, the main once being lactose (45 – 50 g/L). Other compounds include soluble proteins (6 – 8 g/L), lipids (4 – 5 g/L), and various mineral salts, mostly NaCl, KCl and calcium salts, (8 – 10 % of dried extract). Cheese whey

[49] Valta K., Kosanovic T., Malamis D., Moustakas K., Loizidou M. (2015) Overview of water usage and wastewater management in the food and beverage industry, Desalination. Water. Treat. 53 3335–3347, doi:10.1080/19443994.2014.934100

exhibits a high Chemical Oxygen Demand – COD (50 – 70 g/L) and Biological Oxygen Demand - BOD (27 – 60 g/L) [50]. The absence of casein is an important nutritional and technological characteristic.

Cheese whey is commonly used to produce various types of whey cheeses. Examples of whey cheeses include ricotta in Italy and myzithra, anthotyros, manouri and giza in Greece.

Production of cheese wheys can be a meaningful economic activity for cheese producers, but it does little to reduce the volume of residual products that still require further processing. There is limited information in the literature about the mass balances of whey cheese products; an indicative example from literature mentions that in order to obtain 1 kg of ricotta cheese, 15 – 20 litres of cheese whey is needed and the process leads to 14 – 19 litres of secondary cheese whey[51].

Secondary cheese whey retains about 60 % of the dry matter content of the primary cheese whey. Its COD value can reach up to 80 g/L, of which more than 70 % corresponds to lactose, its primary constituent[52]. Considering its production volume and high organic content, secondary cheese whey is a major environmental issue for cheese producers.

Finally, cheese whey wastewater has a more or less similar composition with cheese whey and secondary cheese whey, but lower organic content. Its exact constitution depends on multiple factors, including raw milk type, cheese production process and operator procedures. If no valorisation of cheese whey (e.g. for whey cheeses production) or secondary cheese whey takes places, it is not uncommon to mix those residual streams with cheese whey wastewater and treat them together. Obviously, this process increases the organic content of cheese whey wastewater[53].

4.3 Cheese residues valorisation and treatment options

Cheese whey and secondary cheese whey include significant quantities of protein and lactose because of that exhibit a high COD / BOD content that can cause significant environmental harm if discharged directly to the environment. Their management therefore aims to either valorise some of these useful constituents or neutralize them. This section presents the main options that are available to cheese producers in addition to whey cheese production. Regardless of the method employed, there are some common characteristics of cheese whey and secondary cheese whey that should be taken into consideration and which present various difficulties:

- High possibility of microbial degradation unless it is pasteurized after production.
- High variability in composition, as previously discussed.
- Low concentration of solids, which increases handling costs.

4.3.1 Animal feeding

Cheese whey can be used directly (e.g. in its liquid form) as an animal feed. Liquid feeding in general is considering to have several advantages (e.g. improved nutrient utilization, flexibility and control of feeding programmes, utilization of inexpensive liquid by-products, reduced environmental impact and

[50] Carvalho et al. (2013), ibid.
[51] Mills O. (1986) Sheep dairying in Britain — a future industry. Int J Dairy Technol 39:88–90. https://doi.org/10.1111/j.1471-0307.1986.tb02378.x
[52] Carvalho et al. (2013), ibid.
[53] Carvalho et al. (2013), ibid.

improved animal performance) as well as disadvantages (e.g. consistency of raw material supply, high moisture content, variability in nutrient content, high salt content of some feedstocks, etc.) [54].

Generally, use of cheese whey and secondary cheese whey s quite common and employed mostly in pig farming (especially fattening pigs and lactating sows) and ruminants' feeding. The high water content of these feedstocks place economic limitations to long-distance transportation, hence adoption of this practice requires that pig farms are located in fairly close vicinity to the cheese whey production site.

4.3.3 Physicochemical treatment

Various physicochemical processes are employed to separate different useful fractions from cheese whey and secondary cheese whey: whey powder, whey protein concentrate (WPC), whey protein isolate (WPI), whey permeate (WP), lactose, and minerals. These products have market prices, often high, and their production has an impact on the dairy sector. Some average market prices quoted for North Italy include: cheese whey 25–30 €/t; CW powder for both animal husbandry and human nutrition 1,000 – 1,200 €/t; food-grade lactose is 1,600 – 1,700 €/t; WP 700 – 800 €/t; WPC 35 powder 3,200 €/t; WPC 60 powder 4,900 – 5,200 €/t; WPC 80 powder is 8,500 – 12,000 €/t; CW DEMI50 1,500 – 1,700 €/t; CW DEMI70 1,800 – 1,900 €/t; CW DEMI90 2,300 – 2,600 €/t[55]. Market prices are monitored on the website of CLAL[56], an Italian Dairy Economic Consulting Firm.

Physicochemical methods used for the treatment of cheese whey and secondary cheese whey include spray drying, protein precipitation and membrane filtration (reverse osmosis, ultra-filtration).

4.3.3 Biotechnological treatment

Biotechnological treatment aims to take advantage of the organic content of cheese whey and valorise if either for energy production or for production of various useful products. Several different options are possible[5758,59]: anaerobic digestion, aerobic digestion, fermentative processes (e.g. dark fermentation, lactate fermentation, ethanol fermentation) and bioelectrochemical processing.

Anaerobic digestion (AD) is considered as the "conventional method" for processing cheese whey and cheese whey wastewater, with some authors claiming that it is the only economically feasible option. The high organic content and low alkalinity of cheese whey may lead to the formation of volatile fatty acids, which inhibit methanogenesis. Co-digestion of cheese whey with other substrates, e.g. sewage sludge and dairy manure / sludges is often suggested as a strategy to overcome these issues.

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54 "The Pig Site - What We Know About Feeding Liquid By-Products to Pigs" (www.thepigsite.com/articles/what-we-know-about-feeding-liquid-byproducts-to-pigs - last accessed on 26 March 2021)
55 Zotta T., Solieri L., Iacumin L., Picozzi C., Gullo M. (2020) Valorization of cheese whey using microbial fermentations. Applied Microbiology and Biotechnology 104, 2749–2764 https://doi.org/10.1007/s00253-020-10408-2
56 CLAL website (www.clal.it – last accessed on 26 March 2021)
57 Carvalho et al. (2013), ibid.
58 Zotta et al. (2020), ibid.
59 Asunis F., De Gioannis G., Dessì P., Isipato M., Lens P.N.L., Muntoni A., Polettini A., Pomi R., Rossi A., Spiga D. (2020) The dairy biorefinery: Integrating treatment processes for cheese whey valorisation. J Environ Manage. 276:111240. https://doi.org/10.1016/j.jenvman.2020.111240.

4.4 Market situation in Greece

The Greek cheese production sector has some distinct characteristics that differentiate it from that of other EU member-states. The major one has to do with the raw material used, which is primarily sheep and goat milk. The main cheese product is feta cheese, the production of which was estimated to reach 119,000 tons in 2017, of which 59,000 tons were exported. Another key sector characteristic is the large number of enterprises, with most of the producers having small production capacities. The table below summarizes some key features from the sector.

Table 12: Distribution of enterprises by volume of annual cheese production in Greece[60]

Annual production volume	Number of enterprises	Annual cheese production (1000 t)	Annual production distribution
100 t or less	397	11.01	4.93%
From 101 to 1,000 t	178	53.11	23.80%
From 1,001 to 4,000 t	34	67.22	30.13%
From 4,001 to 10,000 t	7	36.71	16.45%
From 10,001 to 15,000 t	3	34.01	15.24%
From 20,001 to 25,000 t	1	21.05	9.43%
Total	**620**	**223.11**	100.00%

The large share of feta in cheese production has implications for the volume of cheese whey production; it is estimated that 1 kg of feta requires 4 kg of a sheep / goat milk mixture to be produced, meaning that cheese whey is around 75 % of the volume of processed milk. This is lower than the typical value of 90 % frequently found in literature.

4.4.1 Production of whey cheeses

The Greek Food and Drinks Code provides the following formal definition for whey cheeses[61]:

"*Whey cheeses are cheeses produced from strong heating of the cheese whey (with or without acidification) and with or without addition of a) milk, b) milk and milk cream, c) edible sodium chlorine (salt) which can be distributed fresh [some can be distributed after partial dehydration and some after maturing] the moisture content of which does not exceed 70 %.*"

Typical whey cheeses produced in Greece are myzithra, anthotyros, manouri and giza. Whey cheese production is widespread, adopted by a large number – but not all – cheese producers. The table below presents the production distribution of hard & semi-hard cheeses, soft cheeses and whey cheeses in the Greek NUTS3 regions. Not surprisingly, regions with high cheese production, also demonstrate high production of whey cheeses. The Agricultural Dairy Cooperative of Kalavryta estimates that around 65 – 70 % of the cheese whey from feta production is suitable for production of whey cheeses.

60 Source: Eurostat, code: apro_mk_strch
61 Κώδικας Τροφίμων και Ποτών. Άρθρο 83: Γαλακτοκομικά προϊόντα. In Greek (www.aade.gr/sites/default/files/2020-03/83-iss3.pdf - last accessed on 26 March 2021)

Table 13: Production of various cheese types by Greek NUTS3 regions (2013)[62]

NUTS3 Region	Hard & semi-hard cheeses	Soft cheeses	Whey cheeses
Attica	1,661	2,354	227
North Aegean	1,905	3,648	559
Western Greece	4,032	13,818	2,526
Ipirus	3,333	18,604	2,436
Thessaly	9,559	46,959	8,329
Ionian Islands	156	1,182	143
Crete	4,605	1,446	2,481
East Macedonia & Thrace	392	3,395	41
West Macedonia	573	1,981	195
Central Macedonia	5,790	24,541	2,287
South Aegean	1,427	110	5
Peloponnese	1,823	8,549	2,217
Central Greece	337	3,351	305
Total	**35,594**	**129,940**	**22,172**

For cheese producers, whey cheeses have traditionally represented an opportunity to produce a new product from a “raw material” that they had available for free. Nowadays however, cheese producers have to make a decision depending on the price they can get for selling cheese whey for protein extraction (see below) or from the market price they can achieve from whey cheese products, minus any disposal costs for the secondary cheese whey that remains.

4.4.2 Animal feeding

Use of whey and secondary cheese whey is a recorded practice in Greece. The main recipient seems to be pig farms. Transfer of cheese whey to such farms is performed under private agreements between cheese producers and pig farmers. The exact volumes absorbed by the animal feeding market as well as the market price of cheese whey (if any) is not known. Adoption of this management option may be subject to restrictions, the major one being proximity of a farm that can use the material as animal feed.

4.4.3 Extraction of whey proteins

The company Hellenic Proteins S.A.[63] was established in 1995, aiming to produce high quality whey protein products, while also providing a solution to the residue management of cheese production units. Within 1996 and 2007, the company constructed and modernized four units, located in major centres of Greek feta cheese production. A characteristic feature of Hellenic Proteins is that it is one of the few such companies in Europe using cheese whey / secondary cheese whey originating from sheep and goat milk. The four units of the company are:

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[62] “ΕΛΟΓΑΚ / Στατιστικά-Αναφορές: Παραγόμενες Ποσότητες (κιλά) Τυριών ανά Περιφέρεια το 2013”. In Greek. (www.elogak.gr/(S(oeh5nr3ulvbq2i45noh5i0bq))/Elogak/anaforesIsGalaktos.aspx?pagenb=20864 – last accessed on 26 March 2021)

[63] Hellenic Proteins S.A. website (www.hellenicprotein.gr – last accessed on 26 March 2021)

- Epirus Proteins: the first whey processing plant in Greece. It has a processing capacity of 50.000 tons of whey per year and the production of various types of whey protein powder is approximately 3.500 tones.
- Central Proteins: the second plant, with a processing capacity of 50,000 tons of cheese whey and production of 3,000 tons of whey proteins. According to the company, the plant is underexploited.
- Macedonian Proteins: the third in line production plant of the company. It has a processing capacity of 60.000 tons of cheese whey per year, and produces 4,000 tons of various whey proteins and 2,500 tons of powder for new products.
- Achaian Proteins: distinct from the other plants, this unit currently serves as a cheese whey collection and concentration centre. It has the capacity to become a full whey-protein production unit in the future.

According to earlier company data, the company processes 76 % of cheese whey production in Macedonia, 67 % in Epirus, 10 % in the Peloponnese and 6 % in Thessaly; the production capacity of the plants seems underutilized and they can absorb more quantities from the market.

Hellenic Proteins S.A. uses various processing steps in order to produce a wide range of products: pasteurization, ultrafiltration, evaporation, crystallization, drying and packaging. It appears that the production units of the company can process both cheese whey and secondary cheese whey; the former is preferable since it has a higher protein content.

Beyond Hellenic Proteins S.A. various other foreign companies (French and Italian) are active in the Greek market to source cheese whey. Cheese whey appears to have a market price for the purpose of whey protein extraction in Greece, although no specific information as to its level seems available. On the other hand, processing of secondary cheese whey is more costly and related to the extraction of lactose (e.g. for juices).

4.4.4 Biogas production

Treatment of cheese whey / secondary cheese whey in anaerobic digesters for biogas production is a practice that gains steadily ground in Greece. According to the Hellenic Association of Biogas Producers, there are two main types of units using cheese whey as a feedstock.

The first type of such plants are the conventional AD units in Greece using the CSTR (Continuous-flow Stirred Tank Reactor) technology. Most of these accept cheese whey of high organic content. As a rule-of-thumb, biogas plants are willing to pay transportation costs for feedstocks with a biogas yield of 40-50 Nm^3/ton as received or more. Usually, the total quantity and share in the overall mixture of feedstock used does not exceed 10 % and exhibits seasonality. Some AD units may also accept waste whey fractions of lower organic content (e.g. mixed with washing waters or other liquid wastes from the dairy sector). However, these dilute mixtures are not sought after, since they have higher transportation costs and higher costs of AD preheating. AD plants producing biogas for power production reclaim transportation and purchase (if any) costs for feedstock through the feed-in tariff or premium they receive for their electricity production.

A small number of AD units employ the UASB (Anaerobic Sludge Blanket Reactor) which is capable of using cheese production residues with low organic content (e.g. secondary cheese whey mixed with cheese whey wastewater). There is a small number (4 – 5) of such units in Greece installed in cheese production plants[64]. The biogas produced in those cases is not used for power production, but rather for heating the AD reactor and for substitution of fossil fuels in the cheese making process.

4.4.5 Co-treatment with cheese whey wastewater

Finally, there are instances of no valorisation of cheese whey / secondary cheese whey recorded in Greece. A recent study[65] includes the case of a fairly large cheese production unit (capacity of 15 tons of milk per day), in which cheese whey is mixed with cheese whey wastewater and disposed to the municipal sewage treatment system.

It should be noted that illegal disposal of cheese whey in rivers and other surface body waters still occurs. The issue has been discussed recently (June 2020) in the Sub-Committee for Water Resources of the Special Permanent Committee for Environmental Protection of the Hellenic Parliament[66].

4.5 Legal framework in Greece

Communication 155680/8−3−2005 of the Ministry of Environment, Spatial Planning and Public Works (YPECHODE) is one of the earlier public administration documents establishing guidelines for the management of cheese whey / secondary cheese whey. Beyond recognizing the severity of the problem, the Communication proposes that during the environmental licensing of cheese production units, its supply to protein extraction plants or to animal farms for feeding should be the preferred method, while its mixing with cheese whey wastewater and disposal in waste processing units should be the last option. It is suggested that small cheese production units (less than 400 tons of processed milk per year) could be excepted from this measure, especially if there are no pig farms nearby. In such cases, cheese whey could be diverted to central wastewater processing units or treated together with the other liquid effluents of the cheese plant and discharged underground. However, in no way should disposal of cheese whey on surface water bodies be allowed.

JMD Φ.15/4187/266/11.4.2012[67] establishes Standard Environmental Commitments for various economic activities within its scope: general commitments, health and safety aspects, noise, gaseous wastes, liquid wastes, solid wastes and special commitments.

Cheese production units fall under economic activity Code 10.5 “Production of dairy products”. Among others commitments, JMD Φ.15/4187/266/11.4.2012 specifies that operations under this economy activity should comply with requirement E4 for liquid wastes:

- *The cheese whey or lactose serum derived from cheese production should either be made available to specialized installations that use it as a raw material, or in animal farms for feed,*

[64] Known examples are TYRAS (www.tyras.gr/eke-tyras/), La Farm (https://sirmet.gr/essential_grid/la-farm-a-e/) and BIZIOS S.A. (www.bizios.gr).
[65] Valta et al. (2017), ibid.
[66] “ΣΤΟ ΕΠΙΚΕΝΤΡΟ Η ΡΥΠΑΝΣΗ ΤΟΥ ΤΙΤΑΡΗΣΙΟΥ” (https://paidis.com/2020/06/18/%CF%83%CF%84%CE%BF-%CE%B5%CF%80%CE%B9%CE%BA%CE%B5%CE%BD%CF%84%CF%81%CE%BF-%CE%B7-%CF%81%CF%85%CF%80%CE%B1%CE%BD%CF%83%CE%B7-%CF%84%CE%BF%CF%85-%CF%84%CE%B9%CF%84%CE%B1%CF%81%CE%B7%CF%83%CE%B9%CE%BF/ - last accessed on 26 March 2021)
[67] Κ.Υ.Α. Φ.15/4187/266/11.4.2012 (ΦΕΚ 1275/Β` 11.4.2012) Καθορισμός πρότυπων περιβαλλοντικών δεσμεύσεων (ΠΠΔ), κατά κλάδο δραστηριότητας, στην άδεια εγκατάστασης- λειτουργίας, για τις δραστηριότητες που εμπίπτουν στο πεδίο εφαρμογής του Ν. 3982/2011 και κατατάσσονται στη Β κατηγορία του άρθρου 1 του Ν. 4014/2011

or in a central system of waste treatment, or they will used for further processing on-site for the production of other products.

- *Care should be taken so that during washing procedures no dispersion of liquid wastes beyond the site of the facility takes place; liquid wastes from washing should be transferred via pipes, canals or ducts to the processing system.*
- *In any case, treatment of cheese whey and lactose serum should always be according to Communication 155680/8−3−2005 of the Ministry of Environment, Spatial Planning and Public Works.*
- *The producer is obligated to keep a record and provide, if requested, to the competent authority of the Region, with the first semester of each year, the following:*
    - *The details of the recipient and the delivery method of cheese whey (processed or not) or lactose serum.*
    - *Private agreement between the cheese producer and the recipient, in which the annual quantity of cheese whey (processed or not) or lactose serum to be delivered will be determined, along with the transportation documents that ensure that they were made available to the recipient.*
    - *Daily records of milk delivery used in cheese production.*

JMD 838/51008/2019[68] on control of the milk market establishes the obligation for various actors in the milk / dairy sector to submit a Monthly Balance Declaration of, which includes the quantities of milk and dairy products and/or daiy constituents and milk processing "by-products" (cheese whey and secondary cheese whey) purchased and sold during the period.

Commission Regulation (EU) No 68/2013 of 16 January 2013 on the Catalogue of feed materials explicitly mentions several possible feed materials coming from whey, including: 8.17.1 Whey/whey powder, 8.18.1 Delactosed whey/delactosed whey powder, 8.19.1 Whey protein/whey protein powder, 8.20.1 Demineralised, delactosed whey/demineralised, delactosed whey powder, 8.21.1 Whey permeate/whey permeate powder and 8.22.1 Whey retentate/whey retentate powder.

4.6 Cheese production residues: by-products or wastes?

After confirmation from YPEN, it was decided to exclude cheese whey used for the production of whey cheeses from the evaluation of waste or by-product status. Transformation of cheese whey to whey cheeses takes place at the site of the cheese producers and cheese whey is essentially an "intermediate" product for this purpose.

Considering the four criteria that have to be met in order for a production residue to be characterized as a "by-product" according to Article 12 of Law 4042/2012, transposing Article 12 of Directive 2008/98/EC, we evaluate whether cheese whey and secondary cheese whey can be characterized as such for specific applications.

Our assessment is that in the Greek framework conditions both cheese whey and secondary cheese whey fail to meet the first criterion, e.g. certainty of further use, at the current stage of market development. This is attested by both literature examples of cheese production units that mix cheese whey with cheese whey wastewater for disposal in the municipal sewage system as well as by the fact

[68] Κ.Υ.Α. 838/51008/2019 (ΦΕΚ 964/Β' 21.3.2019) Μέτρα ελέγχου της αγοράς του γάλακτος

that illegal disposal of cheese whey / secondary cheese whey on rivers, shores and other surface water bodies still takes place.

However, considering the fact that there are several existing usages of cheese production residues that are closely connected with the wider food and feed industry, we examine whether cheese whey / secondary cheese whey can meet the end-of-waste criteria as set out in Article 13 of Law 4042/2012, transposing Article 6 of Directive 2008/98/EC.

According to Article 13 of Law 4042/2012, a certain specified waste ceases to be a waste in its legal term when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed in accordance with the following conditions:

a. The substance or object is commonly used for specific purposes.
b. A market or demand exists for such a substance or object.
c. The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products.
d. The use of the substance or object will not lead to overall adverse environmental or human health impacts.

The table evaluates whether cheese whey and secondary cheese whey meet end-of-waste criteria for the following purposes: whey cheese production (cheese whey only), direct use as animal feed and extraction of proteins. The results indicate that indeed end-of-waste criteria for these purposes should be established. A draft proposal to this effect is briefly presented in Section 6.2 of this report.

Table 14: End-of-waste criteria for cheese whey and secondary cheese whey

Criterion	Evaluation
a. The substance or object is commonly used for specific purposes	Cheese whey / secondary cheese whey is commonly used for the following purposes: • Direct use as animal feed • Recovery of functional ingredients (e.g. whey proteins, lactose)
b. A market or demand exists for such a substance or object	A market exists for all the uses indicated above.
c. The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	Cheese whey and secondary cheese whey fulfil technical requirements for the aforementioned purposes. Direct use as animal feed is regulated by COMMISSION REGULATION (EU) No 68/2013.
d. The use of the substance or object will not lead to overall adverse environmental or human health impacts	The use of cheese whey / secondary cheese whey for the purposes outlined above does not in itself lead to adverse environmental or human health impacts. Use of cheese whey for extraction of functional ingredients results in the production of significant volumes of liquid effluents. These have to be treated under the waste regime unless end-of-waste criteria are developed for them as well.

Cheese whey / secondary cheese waste not meeting the requirements of the draft JMD or diverted to other treatment (e.g. biogas production in AD plants) should be reported in the Digital Waste Registry under Code “*02 05 wastes from the dairy products industry*” - more specifically under the six-digit code “*02 05 01 materials unsuitable for consumption or processing*”.

5. End of Life Tyres (ELTs)

In recent years the number of tyres used worldwide has increased and is expected to increase even more in the years to come. The global tyre market exhibited moderate growth during 2015-2020. As of 2019, the global tyre market size reached 3.2 billion units and it is expected to reach a volume of 4.0 billion units by 2025[169]. One of the leading factors driving the demand for tyres across the globe is the accelerating sales of passenger vehicles, particularly in the emerging economies. Growing global population, rapid urbanization and rising consumer expenditure capacities have contributed to the escalating demand for passenger vehicles across the globe, especially in developing countries. At present, passenger cars are the leading vehicle segment and hold the majority of the global tyre market share. By 2018 the world sales of passenger cars were approximately 80,000,000 and the commercial vehicles sales was approximately 17,000,000 units[70].

5.1 Tyre statistics

Worldwide demand for car and light commercial vehicle tyres is expected to surpass 50 % of the total tyres produced by 2018. Based on region, Asia-Pacific, including major developing markets like China, India, and Indonesia, is the largest market for tyres globally. The tyre industry has a strong presence in EU due to the new investments in Central and Eastern Europe. Moreover, European tyre companies are entering the top ten of world manufacturers. The following figure shows the major European tyre manufacturer's (members of ETRMA – European Tyre & Rubber Association). The annual sales of tyres for passenger cars and light trucks is higher than 300 million units, whereas the sales for trucks and buses is approximately 14 million units.

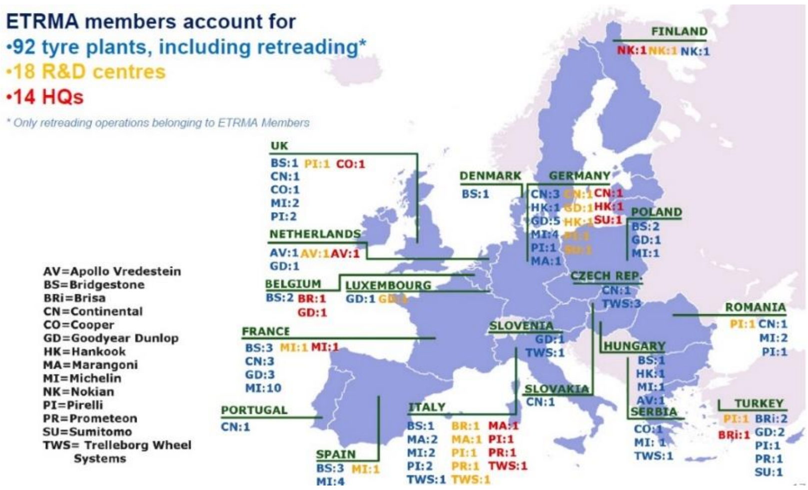

Figure 3: Major European Tyre Manufacturers

69 "Global Tire Market to Reach 4.0 Billion Units by 2025, Impelled by Advent of Ecological Tires" (https://www.imarcgroup.com/global-tyre-market - last accessed on 26 March 2021)

70 "European Tyre and Rubber Industry – Statistics 2019" (https://www.etrma.org/wp-content/uploads/2019/10/20200326-Statistics-booklet-2019-Final-for-web-upload.pdf - last accessed on 26 March 2021)

5.2 Tyres as waste

Tyres constitute a waste that requires treatment as it can cause serious environmental and health issues. Over the past two decades, the rate of rubber waste production in the United States was approximately one tyre disposed per person per year (approx. 290 million waste tyres/ year[71],[72]). Thus, nearly two billion tyres were stored in the United States. Disposal of these high numbers of waste is an issue as they are non-biodegradable, non-condensing, and remain on the surface in landfills. The long-time storage of tyres, without proper management, can lead to fire, toxic hazards and health hazards, while they can also be an ideal breeding ground for mosquitoes that transmit serious diseases. During the previous years, obsolete methods were implemented for tyre management, including disposal to landfills or incineration. In the past a lot of countries have chosen landfill disposal as an option for managing old tyres. However, this option was soon abandoned as tyres occupy a huge volume in landfills and increase the risk of ignition. The impermeability of landfills is not always ensured, which means that hazardous substances generated during the decomposition of tyres can penetrate the ground and affect the surrounding area. In this manner, they may pollute the water and the soil and can have harmful effects on living organisms. Apart from the aforementioned, the burial of the tyres was abandoned as these materials can be reused.

5.3 Management of ELTs

However, in recent years the management of end-of-life tyres (ELTs) has changed, as the legislation regarding their use is becoming more and more stringent. This is also the case at European level, according to ETRMA. Thus, the implementation of new technologies in order to manage ELTs in an environmentally efficient and sustainable way, is imminent. In recent years, several plans have been prepared by the European Union (EU) concerning the management of waste. These plans aim to incorporate the reuse of wastes as raw materials following the norms of the circular economy. A significant amount of the existing solid waste is the end-of-life vehicles (ELVs) and as a result the ELTs. Therefore, these type of waste are very high in EU waste legislation agenda. Thus, EU has included specific directives in this area. Both European and national legislations are mainly based on the extended producer responsibility, concerning those involved in the waste management of their products. In Italy, for example, the disposal of ELTs is carried out by various consortia formed by tyre producers operating at national level and by various authorized recycling companies, which are governed by a specific legal framework.

5.4 European Legislation

Part of the problem can be tackled by using tyres as alternative fuels, after proper treatment. In Europe, the relatively recent Directive 2008/98/EC on the waste management along with Directive 2009/28/EC which subsidizes the biomass fraction of waste, lead to the reduction of landfills, the increase of recycling of special waste streams (tyres) and municipal solid waste (MSW) and in the production of secondary fuels (RDF, SRF, etc.), which are already used as energy recovery materials in

[71] "Wastes - Resource Conservation - Common Wastes & Materials - Scrap Tyres" (https://archive.epa.gov/epawaste/conserve/materials/tyres/web/html/basic.html - last accessed on 26 March 2021)

[72] Pellegrino C., Faleschini F., Meyer, C. (2019) Recycled materials in concrete", Developments in the Formulation and Reinforcement of Concrete (Second Edition), Woodhead Publishing, Series in Civil and Structural Engineering, Pages 19-54

various applications (cement industry, central cogeneration units, large thermal power plants, etc.). "Alternative fuels" is a broad designation that includes any type of non-fossil solid fuel. Biomass fuels or fuels recovered from waste therefore fall within this definition. The list of alternative fuels also includes Tyre Derived Fuels (TDF), fuels deriving from tyres which have reached the end of their life cycle. A list of European directives and regulations concerning the management of tyres is presented on the following Table.

Table 15: European legislation concerning treatment of ELTs

Year	Title - Reference	Content
1975	Council Directive 75/442/EEC on Waste modified by Directive 2008/98/EC on waste and repealing certain Directives	ELTs characterized as non-hazardous wastes
1993	Council Regulation (EEC) No 259/93 on the supervision and control of shipments of waste within, into and out of the European Community	
1999	Council Directive 1999/31/EC on the landfill of waste	Prohibition of the promotion of whole tyres in landfills by 2003, and for shredded tyres by 2006
2000	Commission Decision 2000/532/EC replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste	End-of-life vehicles are coded as “16 01 03”
2000	Directive 2000/76/EC on the incineration of waste	Specific emission standards for the cement industry with effect from 2002. Older cement companies are prohibited from burning tyres at the end of their life cycle after 2008. From December 2008, new treatment for the incineration of waste in the cement industry including used tyres. All cement companies in Europe have already complied with this Directive.
2000	Directive 2000/53/EC on end-of life vehicles	Recovery of 85 % of vehicles to be disposed, with effect from 2006, with compulsory removal of tyres from the vehicle
2001	Commission Decision 2001/118/EC as regards the list of wastes	End-of-life tyres are classified under code 16.01.03, with effect from 1 January 2002 for all members of the Community

Year	Title - Reference	Content
2005	COM(2005) 666 final Thematic Strategy on the prevention and recycling of waste	Overall analysis of the most important achievements in the field of waste management in the last 30 years. The need for additional actions is emphasized in order to determine the optimal environmental options and targets set for waste recycling and recovery, taking into account the differences in products and materials and possible alternatives. The principle of producer responsibility is encouraged - a strategy applied by tyre manufacturers since the late 1990s in anticipation of the European Community regulatory framework.
2008	Directive 2008/98/EC on waste and repealing certain Directives	Setting the basic principles and definitions of waste management and waste management principles such as "the polluter pays" and "waste management hierarchy". Introduces the waste end principle, according to which selected waste streams cease to be considered waste if they comply with specific waste end criteria.
2009	Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC	Mandating the levels of renewable energy use within the European Union from 2009 to 2021
2010	CEN TS 14243 “Materials produced from end of life tyres – Specification of categories based on their dimension(s) and impurities and methods for determining their dimension(s) and impurities”	This technical specification aims to characterize the different materials derived from end-of-life tyres in terms of their dimensions (shredded, chips, powder, etc.) and impurities (wire and textile fiber) using sampling and testing methods.
2018	European Directive 2018/851 amending Directive 2008/98/EC on waste (Text with EEA relevance)	Refers to the need for waste management in the Union which should be done in a sustainable way with the aim of protecting, preserving and improving the quality of the environment, promoting the principles of the circular economy, improving use of energy from renewable sources, etc. Sets the need for each EU country to develop end of waste criteria for different waste streams such as aggregates, paper, tyres and textiles.

5.5 Management systems for ELTs

During the last decade, there has been an increasing number of tyres being discarded as ELTs. The new methods for the treatment of ELTs, tend to engage more environmentally friendly solutions, such as recycling and energy recovery. The EC Directive 1999/31 set the basis for ELT management systems in Europe and within EU nowadays there are three (3) different systems for managing ELTs[73]: i) Extended Producer Responsibility Scheme, ii) Free Market System, iii) Tax System. ELT management schemes in Europe are presented in Figure 2.

Extended Producer Responsibility (EPR) means that the producer is fully or partially (operational and / or financial) responsible for an end-of-life product, thus the original manufacturer has the duty to ensure that the waste from its products is disposed of in an environmentally friendly way, shifting the cost of managing the waste from local solid waste agencies to the producers. Many not-for-profit companies have been initiated and financed by tyre producers in order to manage the collection and recovery of ELTs.

Under the Free Market System, all members involved in the recovery chain of a product contract under free market conditions, acting though in compliance with the legislation. Countries adopting this kind of tyre management are Austria, Switzerland, Germany and the UK. In particular, UK operates a so-called “managed free market” system, as ELT collectors and treatment operators have to report to national authorities.

The third model for managing ELTs is the tax system, where within this type national authorities of each country are responsible for the management of ELTs. Tax is imposed upon tyre producers, which is indirectly paid by the consumer. Croatia and Denmark apply such a management system.

In total, the most widely tyre management system applied in Europe is the EPR scheme used in 21 countries, while some countries are moving from one system to another. EPR tyre system reduces the generation of tyre waste, facilitate its reuse, promote recycling and other forms of material recovery and, finally, incentive the energy recovery.

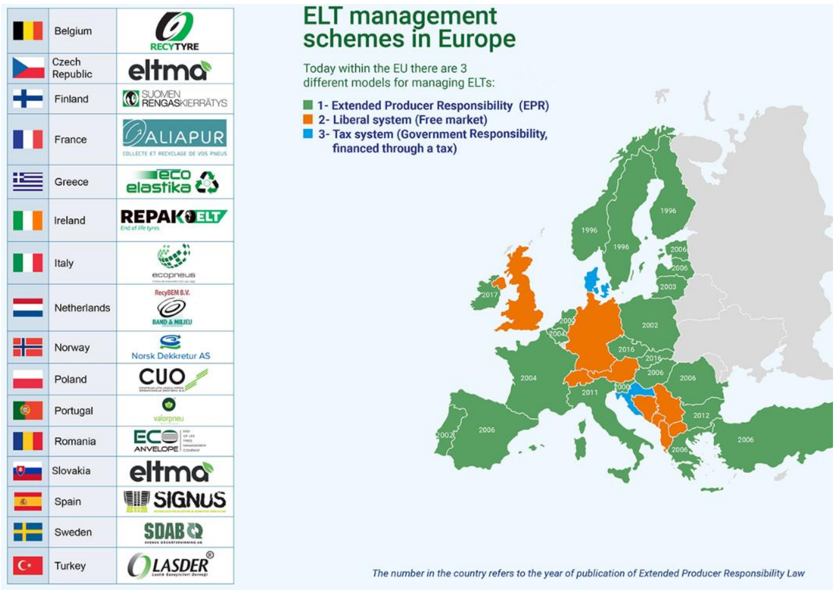

Figure 4: European ELT management schemes

[73] ELTs_A valuable source_2011 (https://www.etrma.org/wp-content/uploads/2019/09/brochure-elt-2011-final.pdf - last accessed on 26 March 2021)

5.6 Management options for ELTs

Based on the aforementioned, ELT management is divided into two subcategories: a) Energy Recovery and b) Material Recycling.

5.6.1 Energy Recovery

Energy Recovery is often applied only to a narrow number of methods for converting wastes into energy, when in fact it applies to a broad range of technologies used to create heat, electricity, or fuel. Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolysis, anaerobic digestion, and landfill gas (LFG) recovery. The economic viability of this alternative route for high temperature resource recovery from tyres is hampered by the fact that the prices obtained for the by-products often fail to justify the process costs. Under current market conditions, the economic viability of these options has yet to be proved, but they have the merit to offer scope for increasing recycling rates.

Recovering energy from waste on a large scale using an advanced incineration plant is a high-cost technology common mainly in developed countries. Open burning of course is discouraged due to harmful emissions and severe air pollution. Tyre Derived Fuel (TDF) made from ELTs seems a cost-efficient alternative to fossil fuels mainly for cement manufacturers, whose energy consumption is one of their largest expenditures. TDF's heat value is almost equal to oil and 25 % better than that of coal. Moreover, its use decreases NOx emissions due to its more efficient incineration[74]. Incineration is the process of combustion for energy recovery and reduction of the waste's volume.

Other thermochemical conversion technologies such as pyrolysis / thermolysis and gasification provide higher energy efficiencies. Moreover, in these processes, less gaseous pollutants are formed, thus lower volumes of combustion gases demand removal. Pyrolysis of ELTs, or thermolysis, is the thermal decomposition occurring under non-oxidative conditions (inert atmosphere or vacuum) which provides intermediate substances such as bio-oil, char and gas. It is also the first step in any gasification or combustion process. The efficiency of the process is much higher (20-30 % higher) when shredded tyres are used instead of whole ones[75]. The products derived from this process may in some cases be used as feedstock for other processes.

The gasification process is more complex than the pyrolysis, as the former is a heterogeneous process where the chemical reactions occur over the surface of the material. Gasification is the partial combustion of organic substances to produce gases that can be used as feedstock (through some reforming processes) or as a fuel. Similarly to pyrolysis, gasification process produces gases with high carbon and hydrogen contents, although the gaseous fraction in gasification is significantly higher when compared to the gases produced by pyrolysis. On the other hand, the oil production in gasification is very low in high temperatures due to thermal cracking, while the char production in low temperatures is comparable to the char produced in pyrolysis.

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[74] "Tyre Recycling Riding On" (https://global-recycling.info/archives/2883 - last accessed on 26 March 2021)
[75] Muzenda E. (2014). A comparative review of waste tyre pyrolysis, gasification and liquefaction (PGL) processes. in International Conference on Chemical Engineering Advanced Computational Technologies, 1-6

5.6.2 Material Recycling

ELTs recycling can provide whole tyres or shredded materials of different sizes and types. Whole tyres can directly find usage in various applications such as coastal protection, artificial reefs, slope stabilization, insulation etc., while shredded materials can be used at cement and automotive industries or can be valuable secondary raw materials for building constructions, asphalt mix and in civil engineering applications. In 2018 material recovery of 1.9 million tons took place mostly by granulation which indicates that 75 % of Europe's ELTs were recycled for this scope annually. In the United States, approximately 300 million tyres are annually scrapped. In 2017, 4.189 million tons of scrap tyres generated, of which 3.411 million tons went to market or were destined for sale – a utilization rate of 81.4 %[6]. Of these, 1,736,340 tons (43 %) were used as tyre-derived fuel in cement kilns, pulp and paper facilities and industrial boilers. 1.013 million tons (25%) got granulated for ground rubber solutions, 315,000 tons (8 %) were used for civil engineering purposes, and 109,000 tons (3 %) were exported. ELTs that are mechanically sheared into shreds ranging in size from 25-300 mm and intended for use in civil engineering applications are called "Tyre Derived Aggregate" (TDA). The following Table summarizes the various applications of TDAs in civil engineering works, sport and safety projects, roads and infrastructures.

Table 16: Civil engineering applications with ELTs[76]

Application	Source				
	Whole Car Tyre	Whole Truck Tyre	Mixed Whole Tyres	Truck Tyre Tread	All Types
Artificial Reefs	x				
Bridge Abutments	x	x			
Concrete Construction Additives					x
Construction Bales	x	x			
Culvert Drainage beds	x	x			
Embankments	x	x	x		
Insulation	x	x			
Landfill Drainage Layer	x	x			
Slope Stabilization	x	x			
Temporary Roads	x	x			
Thermal Insulation	x	x	x		
Collision Barriers					x
Lightweight Fill	x	x	x		
Noise Barriers	x	x	x		
Equestrian Tracks	x	x	x		
Soccer/Hockey Pitches	x	x			
Indoor Safety Flooring	x	x			
Playground Surfaces	x	x			
Asphalt Additives					x

[76] Hylands K.N., Shulman V. (2003) Civil Engineering Applications of Tyres. Viridis Report VR 5, TRL Limited. ISSN: 1478-0143

Application	Source				
	Whole Car Tyre	Whole Truck Tyre	Mixed Whole Tyres	Truck Tyre Tread	All Types
Asphalt Rubber	x	x			
Coatings	x			x	
Expansion Joints	x	x			
Road Furniture					x
Sealants	x				
Surfacing	x	x	x		
Train & Tram Rail Beds	x	x			
Wearing Course	x	x			

5.7 Management of ELTs in Europe

At European level, more than 90% of ELTs are reused in various activities. Initially, ELTs were used for energy purposes, but in recent years their use as secondary material has begun to gain ground. More specifically, in 2018 more than 3.1 million tons of ELT were treated in EU-28, which led to 1,815,220 t of material recovery and 1,150,880 t of energy recovery[77]. This means that approximately 94 % of ELTs were treated. Regarding the recovery of materials, 95,6200 t of ELTs were used in civil engineering projects while the remaining 1,719,600 t were recycled. According to ETRMA, in EU material recovery is gaining ground as an ELT management option[78]. Indicatively, in 1994, approximately 32 % of European ELTs were recovered while 68 % were used for energy purposes. In 2007, the recovery of materials had risen to 54 % while ELTs used for energy recovery reduced to 46% and this proportion continues to change in 2013 to 48 % and 52 % and in 2018 to 58 % and 36 % respectively. Typically, in Germany over the last 20 years recycling has increased its share of ELT management from 13 % to 35 % while treatment for energy purposes reduced approximately by 15 % (from 53 % to 37 %).

5.8 Management of ELTs in Greece

In Greece, ELT's are managed through the "extended producer responsibility" scheme. ECOELASTIKA S.A is the certified collective system responsible for the ELT's management in Greece. ECOELASTIKA S.A., was founded in 2002, by the 5 largest tyre importing companies in Greece, aimed at the creation of a Collective Alternative Management System for End of Life Tyres. ECOELASTIKA S.A. is the only approved Collective System for Alternative Management (CSAM) of used tyres by virtue of Law 2939/2001 and Presidential Decree 109/2004.

ECOELASTICA' System was approved by MD 106157/2004[79] and continued to be valid based on MD 116570/2009[80]. With the decision of 23.11.2011 of the Board of Directors of EOEDSAP (National

[77] "End of Life Tyres Management – Europe 2018 Status" (https://www.etrma.org/wp-content/uploads/2020/09/Copy-of-ELT-Data-2018-002.pdf - last accessed on 26 March 2021)
[78] "End-of-life Tyre Report 2015" (https://www.etrma.org/wp-content/uploads/2019/09/elt-report-v9a-final.pdf - last accessed on 26 March 2021)
[79] Υ.Α. οικ. 106157/2004 (ΦΕΚ 1145/Β` 28.7.2004) Έγκριση του συλλογικού συστήματος Εναλλακτικής Διαχείρισης Παλαιών Ελαστικών «ECO ELASTIKA»
[80] Υ.Α. 116570/2009 (ΦΕΚ 769Β'/13.2.2009) Κανονισμός για τη διαδικασία ανανέωσης των εγκρίσεων συστημάτων ατομικής ή συλλογικής εναλλακτικής διαχείρισης συσκευασιών και άλλων προϊόντων

Organization for Alternative Management of Packaging and Other Products), which has been renamed Hellenic Recycling Organization (EOAN), the renewal of the approval of the System was granted, according to the provisions of Presidential Decree 99/2008 and Presidential Decree 170/2008.

The stages of ELT's management in Greece include: a) Collection of ELT's from dealers all over Greece,b) Delivery of ELT's to recovery units and c) Production and sale of end products and by-products made of ELT's. Tyres are separated to three distinctive categories: a) A – passenger vehicles (average weight 8 kg), b) B – Trucks (average weight 50 kg) and c) C – Moto (average weight 2,5 kg).

It should be noted that ECOELASTIKA's system does not handle tyres with an outer diameter of more than 1400 mm as well as solid (non-pneumatic) tyres for industrial and lifting machines.

Based on ECOELASTIKA's data, the total quantity of tyres introduced in the Greek market in 2019 amounted to 48,860 tons. Out of this quantity, 43,741 tons were tyres that came to Greece through tyre importing companies, while 5,119 tons were tyres that were channelled to the Greek market integrated in imported vehicles. At the end of 2019, the number of tyre importers and vehicle importers that were contracted with ECOELASTIKA was 140 and 68 respectively. The following table presents the new tyres declarations for 2019.

Table 17: New Tyre Declarations in Greece, 2019

	Tires Category A	Tires Category B	Tires Category C	Apparent Weight (tn)
TIRE IMPORTERS	3.861.814	231.986	498.889	43.741
VEHICLE IMPORTERS	573.605	6.530	81.349	5.119
TOTAL	4.435.419	238.516	580.238	48.860
TOTAL (TNS)	35.483	11.926	1.451	48.860

In 2019, ECOELASTIKA managed 96.2 % of the estimated withdrawn quantity of ELTs in Greece. ECOELASTIKA collected the useless vehicle tyres from the following points where the old tyres are replaced with new ones in 2019: a) 1,670 Tyre Dealers, b) 1,128 Vehicle Repair Shops, c) 48 Car Rental Companies and d) 220 Gas Stations. ECOELASTIKA also manages used tyres from other sources including: a) 72 Private companies, wider public sector, Municipalities, Solid Waste Management Authorities, b) 13 Municipalities, Solid Waste Management Authorities, c) 7 Sorting Centers for Recyclable Materials, d) 94 End of life vehicles dismantling facilities and e) 1 Waste management company. In 2019, used tyres were collected from 3,066 initial collection points across Greece and then shipped to recycling or energy recovery plants[81]. ECOELASTIKA collected a total of 43.490 tons of tyres in 2019 and delivered 43.825 tons for utilization, reducing by 334 tons the quantities of used tyres that were in temporary storage areas of collectors. The 65.35 % of the materials produced by the Processing Units were used in recycling applications. The materials produced from the complete mechanical processing of the used tyres in the recycling units in 2019 were 61 % rubber crumb, 22 % iron and 17 % textiles. The remaining 34.65 % of the materials were used for energy recovery (3.05 %

[81] "Annual Report 2019 – Ecoelastica" (https://www.ecoelastika.gr/news/annual_report_2019_EN/ - last accessed on 26 March 2021)

were supplied to the cement production furnaces as inorganic ash and incorporated into the produced product (clinker), while the remaining 31.6 % was co-incinerated).

6. Proposals for the drafting of Joint Ministerial Decisions

6.1 Draft JMD on by-products criteria for olive oil and olive pomace-oil residues

A draft JMD proposal on By-products criteria for olive pomace and other production residues from the olive oil and olive pomace-oil production (exhausted olive cake, olive stones and olive pulp) was developed by Clean Energy. The basis for this legislative proposal is the draft Ministerial Order of the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO) for the categorization of olive pomace as a by-product[82]. The proposal is updated in certain key aspects to reflect conditions in the Greek market. In addition, it includes two dedicated articles covering the by-product characterization of exhausted olive cake, olive stones and olive pulp.

The draft JMD proposal was discussed in late February / early March 2020 with SPEL, as a key representative of the olive pomace-oil sector; the version included in this report already incorporates comments and proposals of the association for the improvement and clarification of the text.

The structure of the JMD is as follows:

Article 1 provides the general framework and clarifies that if management of the targeted residual streams is not in line with the requirements of the JMD, then they should be considered as wastes under the definition of Law 4042/2012.

Article 2 provides the main definitions of the terms used in the JMD.

Article 3 establishes the main conditions for olive pomace to be considered as a by-product throughout the value chain. In particular, mixing of different types of olive pomace (e.g. two-phase with three-phase) is allowed, reflecting industrial practice at the olive pomace mills. Requirements for olive pomace storage are also established.

Article 4 establishes that crude and refined olive pomace-oil should be handled according to agrofood requirements for olive oils and olive-pomace oils.

Article 5 presents the requirements for the olive pomace producers, e.g. the olive mills. It establishes the procedure with which the olive mills declare the olive pomace quantities that are transferred further along the value chain for crude olive pomace-oil production.

Article 6 establishes the requirements for the intermediate and final end users of the olive pomace oil, e.g. olive pomace mills and establishes the procedure with which they declare quantities received and processed as well as the main products and by-products obtained.

Article 7 establishes the control procedure of the Licensing Authority over olive pomace producers, intermediate and final end-users and the processing of collected data for statistical and control purposes.

[82] (FIN DE PLAZO 2020-11-30) Proyecto de Orden Ministerial por la que se determina cuándo los orujos grasos procedentes de almazara y destinados a la extracción de aceite de orujo de oliva crudo se consideran subproductos, con arreglo a la Ley 22/2011, de 28 de julio, de residuos y suelos contaminados (https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/participacion-publica/PP-Residuos-2020-Proyecto-Orden-determina-cuando-orujos-grasos-extraccion-aceite-orujo-subproductos.aspx - last accessed on 26 March 2021)

Article 8 establishes that exhausted olive cake is considered as a by-product for its use as solid biomass fuels for various energy applications. Moreover, requirements for exhausted olive cake and olive stones when used as solid biofuels are established.

Article 9 establishes that olive pulp is considered a by-product for its use as raw material for animal feed.

Article 10 sets the conditions for transferring to or receiving the aforementioned by-products from other EU member states and third countries.

Article 11 updated the term "solid wastes" to "solid wastes and by-products" of previous JMDs in order to avoid any misunderstandings as to the characterization of olive pomace as a by-product.

Article 12 sets the date from which the JMD is in force (upon publication).

6.2 Draft JMD on cheese whey and secondary cheese whey

A draft JMD proposal on end-of-waste criteria for cheese whey and secondary cheese whey was developed by Clean Energy. Unlike olive pomace, no example of declaration of cheese whey / secondary cheese whey as by-products or for the establishment of end-of-waste criteria could be identified in other EU member states. Still, the draft JMD proposal is loosely based on the draft Ministerial Order of the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO) for olive pomace. The proposal is updated in certain key aspects to reflect conditions in the Greek market. The main principle behind the draft JMD is that cheese whey and secondary cheese whey exit the waste status when they are used for two specific applications: animal feed and when used as raw materials for the extraction of various nutritional supplements.

The structure of the JMD is as follows:

Article 1 provides the general framework and scope of the JMD. It clarifies that if conditions of the JMD are not met, then cheese whey and secondary cheese whey should be considered as wastes under the definition of Law 4042/2012.

Article 2 provides the main definitions of the terms used in the JMD.

Article 3 establishes that cheese whey seizes to be a waste when used for animal feed or as raw material for extraction of proteins.

Article 4 establishes that secondary cheese whey seizes to be a waste when used for animal feed or as raw material for extraction of proteins.

Article 5 extends the obligation to submit a monthly milk balance report, covering also cheese whey and secondary cheese whey, to all operators falling within the scope of the JMD (if not already obliged to do so).

Article 6 establishes the control procedure of the Licensing Authority over olive pomace producers, intermediate and final end-users and the processing of collected data for statistical and control purposes.

Article 7 sets the date from which the JMD is in force (upon publication).

6.3 Draft JMD on End of Waste criteria for the production and use of rubber from ELTs

A draft JMD proposal on End-of-waste criteria for the production and use of tyre-derived rubber materials was developed by Clean Energy. The proposal expands on JMD 91808/2020 which defines the basic requirements for products industrially processed from rubber materials or containing rubber materials. A first draft of the proposal was discussed with ECOELASTIKA S.A. in a meeting held in early February 2021; an updated version was produced after receiving feedback from YPEN during the final meeting for the present assignment.

The proposed JMD includes:

1. the type and origin of the raw materials to be declassified as waste
2. the conditions under which the aforementioned materials cease to be classified as waste
3. the conditions for the declassification of the raw materials produced from ELTs and the use of the aforementioned raw material and its applications
4. the quality criteria of the tyre material produced from ELTs
5. the requirements relating to the labelling, marketing and application of the aforementioned material

The Rubber material derived from ELTs cease to be classified as waste at the time of transfer from the producer to the holder, provided that the following conditions are met:

1. Material resulting from recovery processes shall comply with certain quality criteria. These include compliance with the requirements set out in the technical specifications and industry-specific standards (CEN/TS 14243), in order to be used immediately for its intended use, and also complies with additional customer requirements. It must be demonstrated that rubber material derived from ELTs does not exhibit any of the hazardous properties listed in Annex III to Directive 2008/98 / EC and does not exceed the concentration limits set out in Annex IV to Regulation (EC) No 1234/2007. 850/2004. Moreover, rubber materials from ELTs must not contain amounts of oils and lubricants and the categorization of these materials is according to their types and sizes. Compliance with the specifications and legislation for these materials is required (JMD 28492 / 18.5.2009, JMD 27934 / 25.7.2014, JMD 36873 / 2.8.2007, JMD 91808 / 23.9.2020, PD 109/2004) Representative samples must be analysed for each type of rubber derived from ELTs. The Representative samples are taken according to the sampling procedures described in detail in the Quality Management System of the company (sampling method, frequency, size, type and number of samples, statistical analysis, etc.). The physical and chemical parameters are determined in a laboratory accredited according to EN ISO/IEC 17025: 2017.

2. Waste used as incoming materials in the recovery operation shall comply with the following criteria:

a. The only types of ELTs that can be used are those classified as waste under EWC code (16 01 03).
b. ELTs contaminated with dangerous substances cannot be used.

3. Waste used as input material in the recovery operation must be treated in accordance with the following criteria:

a. Materials that coexist in ELTs, such as stones or metal parts, fragmented materials, or other contaminants, should be removed.
b. The methods of processing ELTs must not be hazardous to the environment.

c. Compliance with legislation and regulations related to waste management and treatment (e.g. Law 4042/2012)

4. The producer must meet the following requirements:

a. A statement issued by the producer certifying the characteristics of the rubber material derived from ELTs. For each consignment of rubber material originating from ELTs, the producer / person responsible for the imports into the national territory, shall issue a declaration of conformity of the rubber materials with the criteria set for the declassification of rubber as waste.
b. For each shipment of rubber material deriving from ELTs, the producer shall issue a relevant technical product file, which may be sent or made available to the next holder.
c. The producer implements a quality management system that demonstrates compliance with the quality criteria mentioned above. The quality management system must include a detailed description of the ELTs management. The description should refer to the sampling methodology, the testing of samples, labelling of secondary raw materials, description of packaging and storage procedures. The quality management system must describe the entyre treatment process, including the consequent management and storage of the resulting waste. Compliance with the aforementioned requirements by the producer can be documented by the implementation of a Quality Management System according to the international standard ISO 9001/2015 which is certified by an Accreditation Body.

Finally, the proposed JMD, specifies that the rubber material derived from ELTs are not intended for the following applications: a) combustion, with or without energy recovery, b) cracking, plasmolysis, gasification and related technologies by which the physical or chemical properties of rubber materials are modified, c) landfill and other disposal operations and d) abandonment of materials for a period of more than one (1) year.

The allowed uses of the rubber material are presented on Table 18.

Table 18: Allowed uses of rubber material derived from ELTs

Type	Allowed uses
Rubber from shredded tyres (100 – 300 mm)	1. Landfill constructions – rehabilitation 2. Drainage zones of roads and constructions 3. Insulation 4. Filling material for roads
Tyre Chips - Crumb (0.5 – 6 mm)	1. Surfacing of sport facilities 2. Road construction 3. Shoes 4. Door mats & carpets *5.* Mattresses for pets
Rubber powder (up to 0.5 mm)	1. Wiring material 2. Thermal insulation 3. Sports equipment 4. Bricks, bricks 5. Tire sidewalls

<table>
<tr><th>Type</th><th>Allowed uses</th></tr>
<tr><td>Re-processed rubber powder (up to 50 μm)</td><td>1. Pigments, inks, coatings
2. Car parts
3. Flanges, seals
4. Internal lining of double-walled ships</td></tr>
<tr><td colspan="2">* The use of the rubber material from the processing of ELTs in free form for applications that involve direct contact with soil used for agricultural cultivation and for materials that come in direct contact with food, <u>is not allowed</u>.</td></tr>
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