# Integrated Methodology For Food Byproducts, Surplus And Waste Management

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***Abstract:*** **Optimizing the use of food subproducts and waste is gaining momentum, incorporated into the frame of Circular Economy. In order to support this goal, the current paper proposes cutting edge food waste management procedures for a vast array of uses. These include the production of energy from further processing organic wastes and food subproducts as well as the recycling of carbon and non-carbon-based materials.**

***Keywords: Foodstuff; Wastes; Subproducts; Waste management; Waste processing; Circlular Economy***

## I. Introduction

The current study is under the umbrella of “Research Initiatives for the utilization of wastes produced by company clusters operating in food production”. The Circle of Waste Cluster (CirOWa) is a group of companies engaged in waste processing, specifically produced from the food processing industry. The Cluster has been carefully designed to cover the whole length of the waste production chain and, thus, support the goals of Circular Economy.

Ideally, the result of this action would be the implementation, redesign and optimization of the processes used and the development of strategic cooperation between the stakeholders, in order to achieve an industrial symbiosis, which can create a beneficial (win-win) corporate/economic environment, for all.

## II. The Need

### A. *In numbers*

The food processing industry is an integral part of the Secondary Industrial Sector, covering a basic need of human populations everywhere, in terms of quantity and quality, all the while supporting the economy, regionally, nationally or even in a European and worldwide scale.

Indicatively, in 2020, the annual world meat production reached the 200 mil. tons, the dairy production that of 514 mil. tons while the grain/cereal produce weighted at 2 bil. Tons [1].

Food production is rising in order to support the needs and demands of an ever-growing human population.

According to the Food and Agriculture Organization of the United Nations – FAO (2012) food production must rise up to 60% in a business-as-usual scenario due to population growth and its demands. This rise exceeds the one that was achieved between the 1960s and today [2].

This increased production is expected to add to the volume of byproducts and food waste, increasing accordingly the industry’s environmental impact.

The United Nations Environment Programme - UNEP [3] estimated that 931 mil. tons of food waste were produced during 2019, in a planetary scale, 61% of which were produced in households, 26% from the provision of various food services and 13% from the retail trade of edible produce.

An EU wide study [4] suggests that the Block is producing, annually, 88 mil. tons of food waste (European Union – EU 28), equal to 173 kg per capita, 19% of which is related to the food processing industry.

8-10% of greenhouse gas emissions are, also, directly linked to food wastes, an indicator of their environmental impact [3, 5].

In Greece, the food and beverages industry is the dominant force of the Processing Sector (28.5%) [5]. Furthermore, variables that affect the industry, such as climate change and its after-effects (thermal stress in agricultural areas, farm animal mortality rates, food safety, disruption of distribution) as well as the finite quantity of energy resources, and the worldwide drive for renewable sources, must be taken into account.

### B. *Potential*

All the above are incorporated into the frame of Circular Economy, an effort to generate a sustainable production and consumption model (Fig. 1).

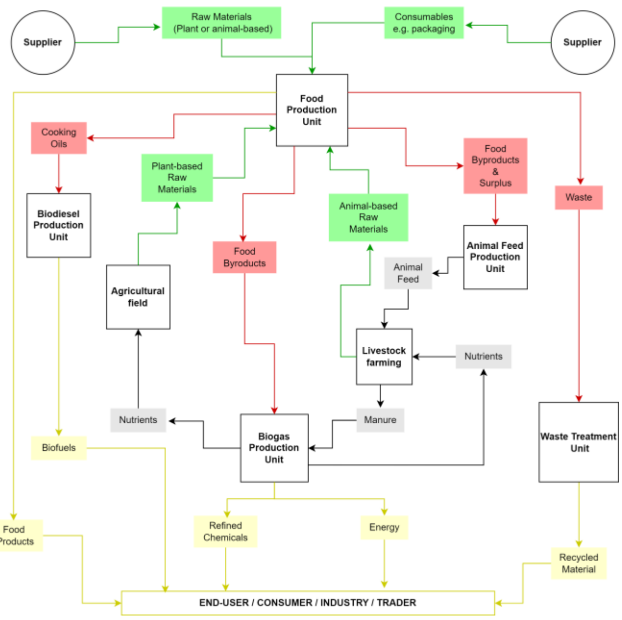


Figure 1. Circular Economy Framework

Harnessing benefits is possible in all sectors of the processing industry. Notably, waste production per product category is distributed as follows: 26% belong to the beverages industry, 21% to the dairy industry, 14.8% to fruit production and process, 12.9% to vegetables production and process, 8% to meat products' processes, 3.9% to the process of plant and animal-based oils, 0.4% to the preservation and process of fisheries and 12.7% to other areas of food processing [6].

The utilization of food wastes is associated with the characteristics of the product in question, and thus its byproducts.

According to a number of studies, food waste can be efficiently used for the production of electrical and thermal energy due to its high content in organic matter [7], an under thorough investigation renewable source, due to its high yield in lignocellulosic biomass (except animal-based byproducts and wastes) [8].

Cellulose and hemicellulose are producing monomer sugars (glucose, xylose), through enzymatic hydrolysis, which are further fermented into ethanol [9]. Through pyrolysis and anaerobic digestion, lignin produces hydrogen ($H_2$) and methane ($CH_4$) [11]. These processes can be utilized for the production of biofuels.

Drawbacks to this concept vary and must be taken into account. Examples are increased microbial activity, which can be intensified by high temperatures or humidity [10] or wastes with high BOD (Biochemical Oxygen Demand) content (such as peels, seeds and total suspended solids) [11].

Efficient waste management must assess these hinderances and find solutions. Related literature proposes a number of alternative processes to achieve this, promoting the optimal way, in respect to the issue arising (Fig. 1).

Study [12] created a tool to support decision making specifically for choosing the most sustainable and optimal food waste utilization process (Food waste management alternatives - FWMAs). It consists of nine (9) assessment stages combined with a group of quantitative parameters, in order to quantify efficiency indicators in economic, social and environmental level. The tool was used in two separate case studies in the United Kingdom (Molson Coors και Quorn Foods).

## III. WASTE CHARACTERISTICS AND INDICATORS

Indicators can be used to assess the potential of a waste management process [13,14]. This potential is described by the waste's content in organic matter, a quantitative parameter. These indicators are defined as follows:

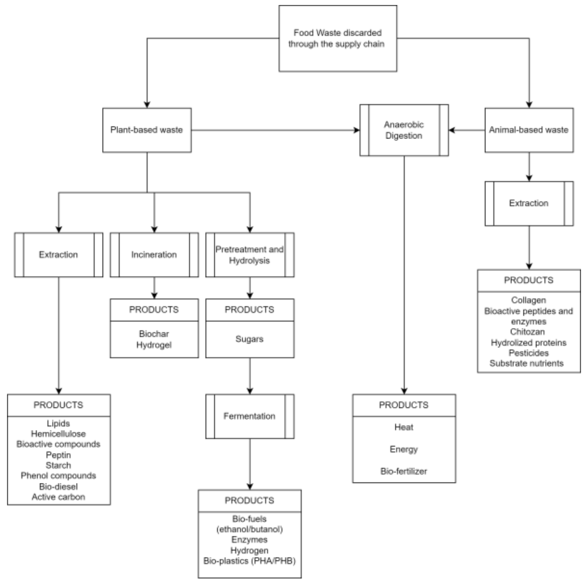


Figure 2. Food waste treatment processes (Ravindran and Jaiswal, 2016).

**Biochemical Oxygen Demand – BOD (mg/L)**: The amount of dissolved oxygen consumed by aerobic biomass in order to biologically oxidize a litre of sample, at specific temperature (T) over a specific time period. Commonly, T = 20 $^0$C during five days of incubation ($BOD_5$). The indicator is used in industrial waste treatment through the term "population equivalent", meaning the number of people needed to produce waste with a specific $BOD_5$ content. The Winkler Method and its variants are most commonly used for the calculation of BOD.

**Ultimate Biochemical Oxygen Demand – UBOD (mg/L)**: The amount of dissolved oxygen consumed by aerobic biomass for the total biochemical degradation of organic matter in a given sample, over "infinite" number of days (20 days).

**Chemical Oxygen Demand – COD (mg/L)**: The amount of dissolved oxygen needed for the total chemical oxidation of the organic matter in $CO_2$ and $H_2O$.

**BOD/COD Ratio**: This indicator is used to determine how biodegradable is a waste. The biological treatment of a waste is more efficient as the indicator reaches 1.

**Total Organic Carbon – TOC**: This particular parameter is used for the analytical measurement of the total amount of carbon present in the organic matter of a waste, preferred in cases of low concentrations, simply by converting all the different forms of carbon to $CO_2$, which is easy to measure quantitatively.

**Theoretical Oxygen Demand – ThOD**: Supporting all the other methods, ThOD is the calculation of the $O_2$ needed to oxidize a known compound to its final oxidation products.

**Total Seattleable Solids – TSS (mg/L)**: Total Solids (TS) of a liquid waste are represented by the solid residue remaining after treating, a filter of known weight, at temperatures of 103 – 105 $^{0}$C, causing the liquids to evaporate. TS are composed by Suspended Solids (SS) and Dissolved Solids (DS), which are able to survive filtration. SS are also composed by Settleable Solids and non-Settleable Solids, with precipitation being held under idle conditions.

**Mean Population Number – MPN:** The pathogen content of a liquid waste (MPN/100 ml of sample), or else, the average number of bacteria found per 100 ml of waste sample.

**pH**: A figure expressing acidity (or alkalinity) by evaluating the concentration (moles/L) of H ions, defined by the equation:

$$pH = -\log10 (H+)$$

**C/N Ratio**: An indicator evaluating the balance between Carbon and Nitrogen.

**Total Kjeldahl Nitrogen – TKN:** The total amount of nitrogen present in a sample, in forms of organic nitrogenous compounds and ammonia.

## IV. WASTE TREATMENT METHODS AND PROCESSES

Residues or pre-cooked meals which produce biodegradable organic waste are called food waste. FAO defines food waste as «quality and quantity losses through the process of the supply chain taking place at production, post-harvest and processing stages» [15].

The European Commission has issued a number Directives establishing a legal framework for the handling of waste in the Community. Directive 2008/98/EC declares that waste treatment must be performed with methods which protect environmental conditions (water, air, soil, plant and animal life) and human health by preventing/reducing adverse impacts and improving resource utilization and its efficiency.

A number of treatment methods already exist for solid and liquid forms of waste. Most common ways of waste handling are landfills (sanitary or otherwise), their use in animal feeds, composting (trench, vermicompost etc.), thermal treatment (incineration, pyrolysis, gasification etc.) and biofuel production (methane, ethanol, hydrogen).

Traditionally, the first goal of food waste handling is the reduction of their volume. For example, incineration can reduce their volume by 90% [16]. The process, though, is energy-intensive and produces harmful gases and ash, which need further treatment. On the other hand, sanitary landfilling, although cheap, does not represent a sustainable solution due to its extensive land use and possible environmental consequences to surface and underground waterways. More importantly, resources and/or energy cannot be recovered, designating the aforementioned methods as non-performing, both environmentally and economically [17].

Currently, food wastes are anaerobically digested for the production of energy or used in composting for the recovery of resources [16].

Food wastes, rich in organic compounds and nutrients, could be, theoretically, an ideal and cheap resource for biogas, biofuel, biofertilizers and other chemical compounds with added value. However, complex and resilient organic compounds present at the waste can complicate the aerobic or anaerobic treatment [16].

Biological processes like anaerobic digestion, aerobic composting, bioethanol and animal feed fermentation etc., have already been studied in terms of resources and energy recovery [16]. Composting emits greenhouse gases and produces leachates capable of causing eutrophication and acidification of local ecosystems [18].

EU-wide guidelines are set to assist in choosing the most efficient and environmentally friendly method to treat and discard food waste. Food waste hierarchy (Fig.2) prioritizes actions that governments and other management authorities can take to prevent and divert wasted food:

- Reduce volume by minimizing food surplus,
- Redistribute food surplus to afflicted groups (e.g. homeless or people struck by food poverty),
- Convert to animal feed and compost,
- Convert to energy by anaerobic digestion,
- Dispose in landfills.

The framework, though, cannot be utilized fully because most food waste cannot be legally converted to animal feed inside the European Union [18].

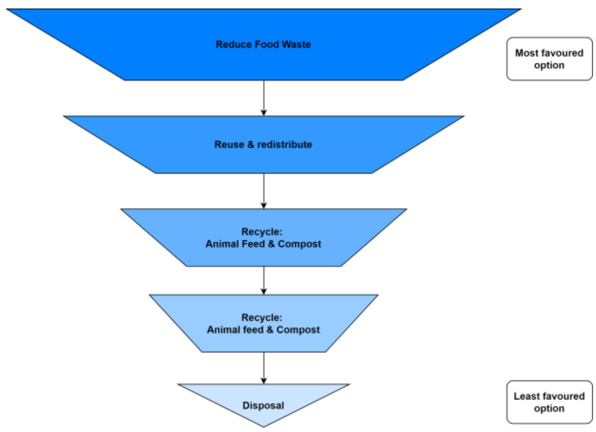


Figure 3. Food Hierarchy (based on [18]).

In addition to treatment methods, edible sub- and byproducts consist of compounds that can be harvested and used by the food and pharmaceutical industries. Bioactive compounds have a favorable effect on human organism and can be found as secondary metabolites in plant-based food waste. Harvesting them can be achieved by extraction (e.g. Soxhlet) or other innovative processes (e.g. microwaves, ultrasonic, superficial fluids etc.). Food waste can also be used as substrate for microbial growth used for the production of proteins, organic acids, bioplastics and enzymes, industrially.

Below (Table I), a summary of various treatment methods is presented, in order to help with the identification of the most suitable one, based on its characteristics and situational use.

TABLE I. Treatment and Processes for Liquid and Solid Waste Utilization

| **TREATMENT & PROCESSES *for* LIQUID AND SOLID WASTE UTILIZATION** | | |
|---|---|---|
| ***1*** | ***USEFULL BIOACTIVE COMPOUND HARVESTING*** | |
| ***1.1*** | ***CONVENTIONAL EXTRACTION METHODS*** | |
| 1.1.1 | Maceration – Solvent Extraction | A separation method of compounds, based on their relative solubilities, in two different immiscible liquids. Organic solvents are, usually, chosen for the treatment of high volumes of waste. |
| 1.1.2 | Soxhlet Method | The standard Soxhlet apparatus consists of a distillation flask, a disposable thimble, a siphon and a condenser. The sample is placed in the thimble and treated with vapors of solvent, produced in the distillation flask, and then are liquified in the condenser. When the liquid reaches the overflow level in the thimble a siphon aspirates the solution and the liquid falls back into the distillation flask, where the separation of solute from solvent takes place. |
| ***1.2*** | ***INNOVATIVE EXTRACTION METHODS*** | |
| 1.2.1 | Microwave Assisted Extraction | A process of using microwave energy to heat solvents in contact with solid waste, in order to harvest the desired compound. |
| 1.2.2 | Ultrasound Assisted Extraction | A process utilizing ultrasonic energy in the form of waves, which passes through a liquid solvent containing solid particles. Rapid and localized increase in pressure and temperature are responsible for the disruption of cellular membranes, thereby facilitating the solvent migration into the cell and consequently, the extraction of the desired compound. |
| 1.2.3 | Supercritical Fluid Extraction | A supercritical fluid is used as the extraction solvent. $CO_2$ is the most common one due to its low critical point, extraction properties, availability, gaseous natural state and safety. After extraction the solvent becomes gas and the analytes are conveniently concentrated in the collecting medium. |
| 1.2.4 | Pressurized Fluid Extraction | The process is carried out statically by applying heat and pressure to extraction solvent and samples, improving the efficiency and extraction speed, by affecting parameters like solubility and rate of mass transfer. |
| 1.2.5 | High Hydrostatic Pressure Extraction | Innovative process that combines the use of room temperature, low volumes of organic solvents, reduction of extraction time and energetic consumption, with higher yields and high-quality extracts. Consists of applying pressures (up to 600 MPa), transmitted by a liquid medium, usually water. |
| 1.2.6 | Extraction by Pulsed Electric Fields | Pretreating process of a waste with electric pulses to destroy microbial and plant cells. It is a non-thermal process that leads to high efficiency extraction, faster and by using less energy. |
| ***2*** | ***LIQUID WASTE TREATMENT*** | |
| ***2.1*** | ***PHYSICAL TREATMENT*** | Use of racks, screens, filtration, sedimentation and flotation processes [19] |
| ***2.2*** | ***CHEMICAL TREATMENT*** | Use of chemical precipitation, disinfection (usually with chlorine or ozone) and ion exchange [19]. |
| ***2.3*** | ***BIOLOGICAL TREATMENT*** | |
| 2.3.1 | Aerobic Processes | Bacteria and other microorganisms consume organic compounds, ammonia and phosphorus producing $CO_2$, $N_2$ and biomass, in aerobic conditions [19]. |
| 2.3.2 | Anaerobic Processes | Anaerobic digestion is a complex process, combining different reactionary pathways |

| | | |
|---|---|---|
| | | like hydrolysis, acidogenesis and methanogenesis. Bacteria break down organic matter in the absence of $O_2$ [20]. |
| ***3*** | ***SOLID WASTE TREATMENT*** | |
| ***3.1*** | ***ANIMAL FEED PRODUCTION*** | The use of treated food waste as animal feed. The preparation stage involves drying, chemical or thermal treatment [18].<br>Untreated food waste, especially animal byproducts, are considered dangerous and are, legally, banned from use. |
| ***3.2*** | ***DISPOSAL TO LANDFILLS*** | Burial is a cheap form of waste management. But, even if sanitary landfill disposal is used, byproducts such as $CH_4$ and leachate are in need of further treatment or can cause significant adverse impacts to the natural recipient (e.g. underground water ways) [21]. |
| ***3.3*** | ***THERMAL PROCESSES*** | |
| 3.3.1 | Incineration | A process of burning waste and hazardous material at temperatures high enough to destroy contaminants and pathogens. Destructive process, which lowers the volume of waste [22]. |
| 3.3.2 | Pyrolysis | A process of heating organic matter, in the absence of oxygen. Usually conducted at 500 $^0$C or above. Reduces the volume of waste and controls greenhouse gas emissions [21]. |
| 3.3.3 | Gasification | A process that converts organic matter into CO, $CO_2$ ¬and $H_2$ (syngas). The process is performed above 700 $^0$C, without combustion, with a controlled amount of $O_2$ or steam. Syngas has high thermal content and can be used in biofuel or energy production, although its use is still limited. The remaining solid waste (char) cannot be treated further [23]. |
| ***3.4*** | ***COMPOSTING*** | |
| 3.4.1 | Conventional Composting | Natural decomposition of organic matter, converting it to a nutrient-rich, biologically stable soil substrate or mulch. Microorganisms are responsible for the process, which takes place in aerobic conditions [24]. |
| 3.4.2 | Hydrothermal Composting | Pretreating the organic matter hydrothermally, before the composting phase, enhances solubility of organic material, improves bioaugmentation and kills harmful microorganisms. A drawback is the creation of furan compounds which hinder microbial activity [25]. |
| 3.4.3 | Vermicomposting | The use of worms as a pretreating stage, stabilize the organic matter and creates a nutrient rich substrate for microorganisms, which take over. Worms also aerate and mix, naturally, the waste mass [26]. |
| ***3.5*** | ***RENDERING*** | |
| 3.5.1 | Wet Rendering | Process of separating animal fat and proteins from tissue. The material remains humid and is separated by decanting [27]. |
| 3.5.2 | Dry Rendering | Process of separating animal fat from tissue. The material is dry and the separation is taking place with the use of pressure [27]. |

## V. MANAGEMENT SYSTEM (MS)

The proposed MS (Table III) is implemented in productive and processing industrial units, at the whole length or in parts of the production line.

It refers to the activities detailed below:

- Management of food byproducts and waste treatment, for various uses,
- Management of food byproducts and organic waste treatment, for energy production,
- Treatment and recycling of carbon and non-carbon-based waste.

### A. *Key Concepts*

**Treatment:** Any method of reclamation or disposal, including preparatory stages.

**Reuse:** Activities reputing to use materials, not considered waste, for the same purpose that were produced for.

**Reclamation**: Waste products are repurposed and used in different activities, replacing other raw materials.

**Recycling:** Any recovery operation by which waste materials are reprocessed into products for the original or other purposes.

**Disposal:** Any activity which does not constitute reclamation, even if useful materials and energy are produced as a side effect.

**Collection:** Any method of waste handling and consolidation, from various sources, like separate collection and primary storage, including transfer practices.

**Byproduct:** A secondary product of a production line that:

1) Can be used for other purposes,

2) without further treatment, except usual industrial procedures.

**Waste Management:** Coordinated actions for safe collection, treatment and disposal of waste material.

**Management:** Coordinated actions for achieving well-defined goals and controlling the operations of a company.

**Management System:** A set of joint and interactive corporate actions, supporting policy making, processes and production targets.

**Audit:** Systemic, independent and evidence-based process for assessing operational activity by specific and universally accepted standards.

**Non-compliance:** Practices leading to results that do not conform to universally accepted standards, company targets, legislation or other regulatory means.

**Rectification:** Action targeting non-compliances or other unwanted situations.

**Optimization:** Actions and practices aiming to improve the efficiency of used processes.

### B. *Operating Framework*

Internal corporate parameters, like a company's strategic direction, mission, vision, values, culture, resources, operational knowledge and performance, require constant observation and evaluation. The Management System is implemented, maintained and evolving in terms of its efficiency. External corporate parameters, affecting organizational activity are the economic, social and legal environment and their relationship, as well as market forces and competition. Technological innovation in every sector increases the demand of adaptability on every stakeholder. Frequent and substantial educational activities for every collaborator of the project is key to stay up to date with technological achievements and breakthroughs.

All interested parties are affecting production activities, waste management and treatment, and play an integral part in the implementation of the System's directives, the legal and regulatory obligations. Possible stakeholders are recognized as follows:

- The employees,
- Corporate partners,
- Public Authorities,
- The Ministry of Energy and Environment,
- Residents in the area,
- Other operating companies or production units in the vicinity.

All stakeholders are required to:

- Have a well-defined production process.
- Ensure that their operational activities do not have an irreversibly adverse environmental impact in local and regional (or other geographical) scale (e.g. pollution of underground water, noise pollution, etc.),
- Abide with environmental regulations.
- Prove a company's sustainability.
- Follow directives defined by the legal framework and other regulatory authorities.
- Anticipate hazards and be prepared for a disaster.
- Utilize any opportunities.

### C. *Objects*

The MS is composed by a set of well-defined processes, that should be supported with the required resources, in every step, in order to achieve their goals.

Each process is defined by a method of action or object, namely, a written directive on how input data will be transformed to results. The following Table (Table II) correlates processes to objects.

TABLE II. Correlation of Processes to Objects

| O/N | PROCESS | CODE | OBJECT |
|---|---|---|---|
| .01. | **System Design** | MS.C.01.01 | Documentation and filing system. |
| | | MS.C.01.02 | Educational and training activities. |
| | | MS.C.01.03 | Legislation and Regulations |
| | | MS.C.01.04 | Internal Audits |
| | | MS.C.01.05 | Non-Compliance Rectification |
| | | MS.C.01.06 | Reviewing |
| .02. | **Production Management** | MS.C.02.01 | Byproduct and Waste Identification |
| | | MS.C.02.02 | Characterization |
| .03. | **Waste Treatment & Handling** | MS.C.03.01 | Choosing a Suitable Treatment |
| | | MS.C.03.02 | Optimization |

### *D. Processes*

**Production Management:**

#### *1)* Byproduct and Waste Identification

Byproduct and waste quantities and qualities are linked to the operational scale of a company, the production methods, the quality of raw materials and the final product. Their production can be intermittent or constant.

The Identification Stage (Fig.4) is essential for:

- Choosing the appropriate treatment and handing methods.
- Utilizing waste for the production of other useful products.
- Cutting operational and treatment costs.
- Abiding to environmental legislation and regulations.

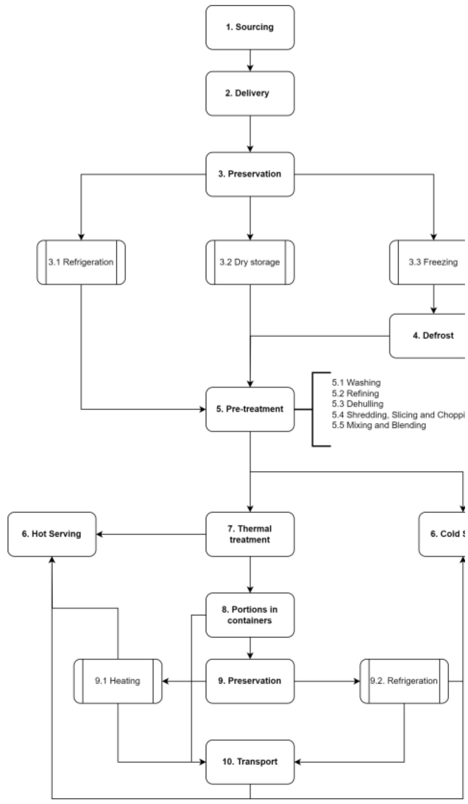


Figure 4. Identification Process

#### *2)* Characterization

To identify waste and byproducts a sampling method must be put to use, followed by analysis, data collection and interpretation.

Collection practices, equipment, sampling stations and timing are important milestones of the decision-making process.

This Stage is responsible for recognizing features of a waste like composition, biodegradability and hazardous traits.

The use of indicators mentioned before, such as BOD, COD or C/N, is apparent for the appropriation of important physical and chemical properties, as well as the organic content, in other words, its hidden potential.

**Waste Treatment and Handling**

#### *3)* Suitable Treatment

After identifying byproducts, choosing the best-suited treatment method is important operationally.

Except the physical and chemical traits of the waste, the choice depends on the layout of the production line, capital investment caps, legislation and regulations.

Other important questions that need answer are how the preferred waste treatment interacts with production activities and if a byproduct can be launched as a new service, considering market forces and consumer needs.

#### *4)* Optimization

A continuous phase of taking the operational feedback of a process used to treat waste material, and converting it to applied actions in order to improve the efficiency of the process, targeting operational, logistical and energy costs while boosting yields.

TABLE III. Management System Documentation.

| PROCESS | CODE | OBJECT | FILE | TYPE |
|---|---|---|---|---|
| System Design | MS.C.01.01 | Documentation and filing | Approved MS File | F* |
| | | | Document (re-)issuing | D** |
| | | | Internal Distribution | D |
| | | | Distribution to third parties | D |
| | MS.C.01.02 | Educational and Training activities | Program | F |
| | | | Calendar | F |
| | | | Material and work instructions | D |
| | | | Distribution | D |
| | MS.C.01.03 | Legislation and Regulations | Updated Law and Regulations' List | F |
| | MS.C.01.04 | Internal Audits | Calendar | F |
| | | | Report | D |
| | MS.C.01.05 | Non-compliance rectification | Report | D |
| | | | Registry | F |
| | MS.C.01.06 | Review | Report | D |
| | | | Supervisor's Proposals | D |
| Production Management | MS.C.02.01 | Byproduct and Waste Identification | Raw material's Registry | F |
| | | | Waste Registry | F |
| | | | Operational Flow Chart | D |
| | MS.C.02.02 | Characterization | Indicators' Registry | F |
| | | | Instrument Calibration | F |
| Waste Treatment and Handling | MS.C.03.01 | Choosing a Suitable Treatment | List of Treatment Methods | F |
| | MS.C.03.02 | Optimization | Indicators' Registry | F |

**F: File, **D: Document*

## VI. INTERCONNECTIVITY WITH ON-LINE PLATFORM

The interconnection of the proposed MS to an online application is deemed necessary and advantageous, providing efficient management of data, through dynamic verification workflows and check lists.

CirOWa Cluster participants register operational information creating a common digital workspace where shareholders can communicate and align activities.

Through the application, a product is connected to a production unit(s) and storage facility(s). Quantities, characteristics and certifications can be displayed, while logistical information (e.g. transportation roots and timeframe) can be clarified.

Fig. 5 shows an indicative integration of the MS to the online platform. Next figures are examples connected to a stage of Fig. 5 by the number in the brackets (fig. 6, 7, 8, 9):

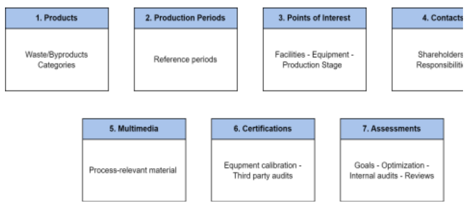


Figure 5. Indicative MS on-line integration.

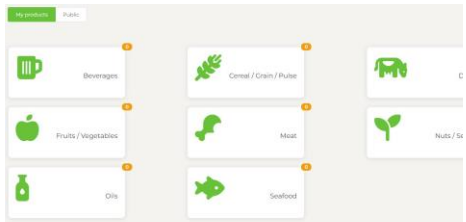

Figure 6. List of Products (1).

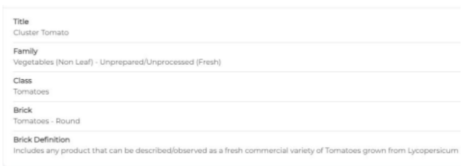


Figure 7. Indicative produce (1).

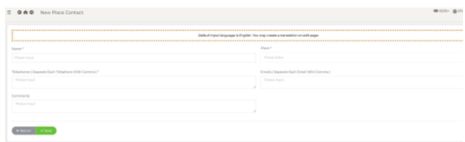

Figure 6. New Place Contact (3).

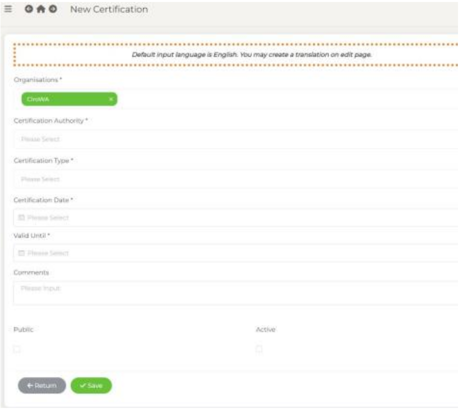


Figure 8. Certifications (6).

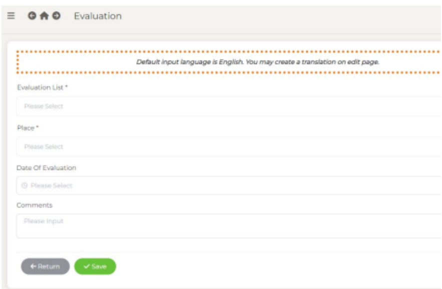


Figure 9. Evaluations (7).

## VII. ADVANTAGES

The proposed MS, similarly to ISO standards, combines corporate goals like optimization, fruitful auditing and rectification practices, a company's image, work ethic and consumer satisfaction with environmental protection.

By providing a set of well-defined and measurable targets, it is in a position to effectively assist corporate strategic pursuits. Furthermore, it promotes efficient management and allocation of resources, without hindering operational activity.

Regarding operational costs, the MS, by being fully compatible with existing corporate practices, (e.g. Quality Control, Alignment with Food and Environmental Standards), will not put a strain to a company's finances. Alternate energy and materials' sources, benefits derived from treated waste and byproducts, will, further, cut down variable expenses.

Compatibility with on-line applications and tools permits real time information sharing between shareholders, in an easy-to-use interface.

The proposed MS is a flexible, cost-effective management tool, adaptable to a dynamic corporate world.

## VIII. CONCLUSIONS

The aforementioned Management System is the conceptual design of an effective byproduct and waste treatment process, for energy production and/or materials reclamation, incorporated into the framework of "Research Initiatives for the utilization of wastes produced by company clusters operating in food production" and the CirOWa Cluster. According to the advantages, analyzed in the previous chapter, the MS offers assistance in understanding and handling a complex production environment, with multiple byproduct and waste sources, which can, potentially, be utilized.

To further develop and optimize processes, databases must be composed and stay updated, correlating waste and byproduct properties to quantifiable indicators, ready for use in dynamic, operational conditions.

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## REFERENCES

[1] D. Makris, "Utilization of Agro-Food Wastes Part I-Wastes of the food industry," 2020, .

[2] E. Gladek, M. Fraser, G. Roemers, O. Sabag Muñoz, E. Kennedy and P. Hirsch, "Global Food System: An Analysis - Metabolic," WWF Netherlands 2017, .

[3] H. Forbes, T. Quested and C. O' Connor, *Food Waste Index Report 2021*, 2021.

[4] Å. Stenmarck, C. Jensen, T. Quested, G. Moates, B. Cseh, S. Juul et al., *Estimates of European Food Waste Levels*, 2016.

[5] Foundation for Economic & Industrial Research, "Food and Beverage Industry - Facts and Figures," 2022, .

[6] A. Baiano, "Recovery of Biomolecules from Food Wastes — A Review," 2014, pp. 14821–14842.

[7] S. Otles, S. Despoudi, C. Bucatariu and C. Kartal, "Food waste management, valorization, and sustainability in the food industry," Food Waste Recover. Process. Technol. Ind. Tech. 2015, pp. 3–23.

[8] R. Ravindran and A.K. Jaiswal, "Exploitation of

Food Industry Waste for High-Value Products," Trends Biotechnol. 34 2016, pp. 58–69.

[9] S.P. Das, R. Ravindran and S. Ahmed, "Bioethanol Production Involving Recombinant C . thermocellum Hydrolytic Hemicellulase and Fermentative Microbes C . thermocellum Hydrolytic Hemicellulase," 2012, .

[10] A. Nayak and B. Bhushan, "An overview of the recent trends on the waste valorization techniques for food wastes," J. Environ. Manage. 233 2019, pp. 352–370.

[11] D.S. Sogi and M. Siddiq, "Waste management and utilization in vegetable processing," Handb. Veg. Veg. Process. Second Ed. 1–2 2018, pp. 473–492.

[12] G. Garcia-Garcia, E. Woolley and S. Rahimifard, "Optimising Industrial Food Waste Management," Procedia Manuf. 8 2017, pp. 432–439.

[13] A. Vlisidis, "Liquid and Water Waste Characteristics," 2007.

[14] X. Dimou, "Liquid waste characteristics," 2021. .

[15] P. Sharma, V.K. Gaur, S.H. Kim and A. Pandey, "Microbial strategies for bio-transforming food waste into resources," Bioresour. Technol. 299 2020, pp. 122580.

[16] Y. Ma and Y. Liu, "Turning food waste to energy and resources towards a great environmental and economic sustainability: An innovative integrated biological approach," Biotechnol. Adv. 37 2019, .

[17] X. Xin, Y. Ma and Y. Liu, "Electric energy production from food waste: Microbial fuel cells versus anaerobic digestion," Bioresour. Technol. 255 2018, pp. 281–287.

[18] R. Salemdeeb, E.K.H.J. zu Ermgassen, M.H. Kim, A. Balmford and A. Al-Tabbaa, "Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options," J. Clean. Prod. 140 2017, pp. 871–880.

[19] I. Woodard & Curran, *Industrial Waste Treatment Handbook*, Elsevier Inc., 2006.

[20] M. Sperling, *Wastewater Characteristics, Treatment and Disposal*, in *Biological Wastewater Treatment Series*, IWA Publishing, 2007, pp. 163–277.

[21] S. Kim, Y. Lee, K.Y. Andrew Lin, E. Hong, E.E. Kwon and J. Lee, "The valorization of food waste via pyrolysis," J. Clean. Prod. 259 2020, pp. 120816.

[22] A.A. Patil, A.A. Kulkarni and B.B. Patil, "Waste to energy by incineration," J. Comput. Technol. 3 2014, pp. 12–15.

[23] A. Molino, S. Chianese and D. Musmarra, "Biomass gasification technology: The state of the art overview," J. Energy Chem. 25 2016, pp. 10–25.

[24] M.P. Bernal, S.G. Sommer, D. Chadwick, C. Qing, L. Guoxue and F.C. Michel, "Current Approaches and Future Trends in Compost Quality Criteria for Agronomic, Environmental, and Human Health Benefits," Adv. Agron. 144 2017, pp. 143–233.

[25] K. Nakasaki, H. Mimoto, Q.N.M. Tran and A. Oinuma, "Composting of food waste subjected to hydrothermal pretreatment and inoculated with Paecilomyces sp. FA13," Bioresour. Technol. 180 2015, pp. 40–46.

[26] V.K. Garg, S. Suthar and A. Yadav, "Management of food industry waste employing vermicomposting technology," Bioresour. Technol. 126 2012, pp. 437–443.

[27] *Agricultural Waste*. Department of Veterinary Medicine, Aristotle University of Thessaloniki, Thessaloniki, 2024.