WaysTUP!

VALUE CHAINS FOR DISRUPTIVE TRANSFORMATION OF URBAN BIOWASTE INTO BIOBASED PRODUCTS IN THE CITY CONTEXT

D1.3: Catalogue of urban biowaste solutions and good practices examples

WP1 – Identification of opportunities and barriers to utilisation of urban biowaste sources

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EXECUTIVE SUMMARY

This is a first short version of the deliverable 1.3, related with the task 1.2.: Catalogue of urban biowaste valorization solutions and good practices examples. This document will be completed and expanded when the task 1.2 gets finished at the end of M42, when by then it will be submitted the Final version of this deliverable.

A summary of the different technologies found at a bibliographic level is shown in this Catalogue. All of the mentioned solutions use the same type of feedstocks as those proposed in the WaysTUP! project; these include: meat by-product, fish by-product, spend coffee waste, source separated biowaste, used cooked oils, cellulosic rejections of MSWTP, nappies, carton and paper rejection of MSW, sewage sludge, olive oil mill waste and sawdust.

In the same way, it has been tried to include technologies that allow to obtain the same type of biobased products proposed in the WaysTUP! Project, as bioenergy products, nutrients, additives or food ingredients, proteins from human food or animal feed, bioplastics, intermediate chemicals, etc.

For each one of the technologies identified, it has been analyzed the following type of information: market readiness, innovation level, environmental added-value, fulfilment of legal requirements, actors involved and roles, barriers to replication in other European countries and applicability of indicators.

In all cases it has been tried to find quantitative data that can be weighted by different indicators in the second phase of this task, which will consist on a multicriteria priorisation of different indicators for all the urban biowaste solutions and good practices.

To sum up, the aim of this deliverable is to show a catalogue of urban biowaste valorisation solutions and good practices that are taking place in the different European countries, which is what it is shown in this First Version, and in the Final version it will be completed with a multicriteria priorisation which permits to obtain a catalogue prioritized taking into account the different indicators that will be proposed.

1.INTRODUCTION

This document presents a bibliographic research of the different alternatives for the use of biowaste in the framework of the circular economy.

Traditionally, most of the biowastes are landfilled and although it is considered as the last option under the waste management hierarchy, landfilling remains the most widely used method of MSW disposal in the EU. Landfilling represented an irrecoverable loss of resources and land, is not considered a sustainable waste management solution in the medium to long term and therefore is not an appropriate option in terms of sustainability.

Among the recovery operations, the most common ones are still composting and anaerobic digestion to obtain biogas. However, today, within the framework of the circular economy, one of the challenges for the management of biowaste is to develop new recovery technologies to obtain biobased products with great potential and to create new value chains at the environmental, social and economic levels.

At this time, many planned and ongoing research activities are aimed at developing alternative methods of harnessing residual biomass and urban biowaste to combat climate change and soil quality degradation. These value recovery alternatives other than composting and anaerobic digestion can transform municipal waste into biobased products with a high potential to be used in different processes of elaboration of new products or add value to original products.

This deliverable shows a catalogue of best practices and solutions applied to the management of biowaste at a European level, results of a bibliographic research. The research was focused on the use of biowaste with a high potential value as raw material, such as wastes or byproducts from food preparation and processing (meat and fish), coffee grounds, used cooking oils, separate organic collection fraction, sludges from sewage treatment plants, cellulosic rejections, nappies, carton and paper rejections, olive oil mill waste and sawdust.

On the other hand, it has been tried to identify those technologies that are also focused on the production of bioenergy products (bioethanol, biodiesel), nutrients, additives or food ingredients, proteins from human food or animal feed as well as for the production of other products with industrial interest such as bioplastics, intermediate chemicals, etc.; all of them also raised in the Pilots proposed in this Project.

As an example of good practice, the most appropriate methods were sought to reduce the use of natural resources as raw materials by preparing substances with higher added value with sufficient quality and safety. All the obtained products are functionally biobased compounds

based on organic matter and therefore biodegradable, with a lower environmental impact. In addition, they must meet a number of very demanding requirements to comply with the relevant international legislation (REACH, food regulations...).

From each of the technologies, the available information has been analyzed to obtain information on the innovation level, environmental added-value, legal requirements, the different actors involved, and other possible barriers, with which the multi-criteria analysis will later be carried out.

Thus, in the framework of the circular economy, it is evident that different recovery technologies are being carried out in a semi-industrial scale production in which a wide range of products such as bioplastics, biofuels or protein production are involved.

2.TECHNICAL SOLUTIONS PER TYPE OF BIOWASTE

2.1. Meat byproduct

Meat by-products such as blood, bones, meat clippings, skin, fatty tissues, horns, helmets, feet, skull and viscera, among others, are costly to treat and dispose of ecologically. There is a wide variety of meat products, but in general, most of them contain good amounts of nutrients such as essential amino acids, minerals and vitamins. Meat byproducts may be considered as raw materials for the generation of biomolecules of interest such as protein hydrolysates with relevant bioactivities or enzymes, extracts with functional properties or bioactive peptides. Other applications target non-edible products such as fertilizers, substances of interest to the chemical and pharmaceutical industry or power generation.

Different innovative technologies are presented below to obtain, through the recovery and recycling of animal proteins, biofuels and organic fertilizers.

2.1.1. Protein recovery and recycling from animal by-products process

The animal by-products can be used as feedstock in order to produce added value products. According to the European Fats Processors and Renderers Association (EFPRA), 328 million pigs, goats, beef and dairy cattle and 6 billion poultry are slaughtered in the EU each year, as the rendering plants process some 12 million tonnes per year of low-risk animal by-products.

LIFE byProtVal project [1] proposes the use of these by-products as raw materials for the production of two higher added value products: tanning agents and amino acid-based fertilisers or biostimulants by recovering valuable collagen derivatives from greaves and wastewater produced in both wet and dry rendering facilities.

The technological procedure is based on recovering valuable protein derivatives from greaves, processing water produced in rendering facilities and meat industries and identifying potential applications for recovered collagen derivatives. The final products of this process are fertilizers and tanning agents, based on recovered protein hydrolysates.

2.1.1.1. Market readiness

The described technology is not ready for market exploitation, as the byProtVal project intends to make a pilot case of the protein recovery and recycling from animal by-products process by developing a pilot plant in Spain.

2.1.1.2. Innovation level

The project plant will consist of two units that will pilot case technological novelty in terms of the treating process and potential applications. Specifically, Unit 1 will treat greaves and advance the enzymatic process trialled in an earlier project INESCOP [2]. Unit 2 will treat processing water using a series of technologies never before applied to this waste stream: isoelectric precipitation, microfiltration and electrocoagulation. Furthermore, the pilot will test the potential applications for recovered collagen derivatives that may be used in fertilisers and chemical products or in the tanning industry or as animal feed.

2.1.1.3. Environmental added-value

Since the pilot is in progress information for the environmental added-value cannot be obtained. However, the pilot process aims to consume 50% less water, compared to similar technologies, by recirculating the recovered water and improve the quality of the discharged water by 50%.

2.1.1.4. Fulfilment of legal requirements

In terms of legal requirements, the ABP Regulation allows different applications for animal by-products, depending on their risk category. Hence, the legislative context exists in order to justify the protein recovery and recycling process, because its main feedstock belongs to the 3rd animal by-product category that is classed as low risk. However, Category 2 products are almost exclusively used for energy production, which is the last recommendation according to the EU's Circular Economy strategy, or are disposed of in authorised landfills, while Category 3 products are mainly used for the manufacturing of animal feed.

The project also contributes to the goals of the proposed Regulation on organic fertilisers, and to the implementation of the Waste Framework Directive, the Renewable Energy Directive and the Water Framework Directive.

2.1.1.5. Actors involved and roles

In the project implementation participates an interdisciplinary team that consists of four partners. Each partner offers experience in different fields such as technological process, end-product exploitation and R&D. The actors involved are following:

Energygreen Gas Almazan S.L. (EGA) is a new company dedicated to the management of non-hazardous waste through different technologies such as anaerobic digestion and rendering. EGA has extensive experience in process and plant design, plant operation and R&D project management.

El Horreo is a family-owned SME with more than 100 years of experience in the preparation of traditional meat products adapted to new consumption trends. Within byProtVal project, El

Horreo participates in the recovery of proteins from the wastewater strains generated in its different production lines.

TRUMPLER is a multinational Company dedicated to the design, synthesis, production and commercialization of leather chemicals and fertilisers.

NESCOP is a technology and innovation center with experience in providing technology services, transferring knowledge and carrying out research on technical topics that are of interest to the industry.

2.1.1.6. Barriers for replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.1.2. Valorization of pig carcasses through their transformation into biofuels and organic fertilizers

The VALPORC[3]initiative aims to demonstrate a process for the sustainable alternative to the management of pig carcasses, focusing on the environmental problems derived from its current management and valorizing these wastes by transforming them into biofuels (biogas and biodiesel), with the corresponding environmental and socio-economic added value.

To achieve this goal, the technology used will involve the following parameters[4]:

- Production of high-quality meal and fat for valorization as biofuel, through an energy efficient treatment process of pig carcasses that meets the health and safety requirements of current legislation for this type of wastes.
- Production of a second-generation biodiesel from animal fats from category 2, by demonstrating an innovative and efficient process based on cavitation technology.
- Use of meat and bone meal from category 2 and glycerin as new substrates for biogas production by their co-digestion with pig manure.
- Implementation of new pre-treatment systems, based on ultrasonic technology, that improve the efficiency of the anaerobic digestion from the substrates used in the project Obtaining a high-quality organic fertilizer.

2.1.2.1. Market readiness

The valorization of pig carcasses will be implemented for a prototype treatment process for pig carcasses to obtain high-quality meal and fat for subsequent use. This process will be tested in a prototype plant, which is 1 or 2 steps before the market exploitation.

2.1.2.2. Innovation level

A prototype treatment process for pig carcasses is about to be developed in order to obtain meal and fat subsequent use. Furthermore, a second-generation biodiesel from animal fats will be produced through demonstration of an efficient and innovative process based on cavitation technology. In addition, using ultrasonic technology an implementation of new pre-treatment systems will boost the anaerobic's digestions.

Specifically, in the transesterification reaction stage, the fat is converted into methyl esters and glycerin, using a catalyst (NaOH) and methanol. To reduce energy consumption at this stage, mass transfer improvement technologies have been developed based on the intensification of this transfer. This improves the reaction rate, reduces the required molar ratio of alcohol / oil, reduces the necessary energy and facilitates the separation of the final product. Within these technologies, it has been demonstrated that the hydrodynamic cavitation reactor is the most efficient in the production of biodiesel.

2.1.2.3. Environmental added-value

A 100% reduction of contaminant emissions (CO_2, NOx, dioxins and furans) is expected to be achieved related to the current management of pig carcasses by incineration. Flexible operating conditions will optimize energy efficiency during this particular process.

2.1.2.4. Fulfilment of legal requirements

The entire project will meet all the ABP Regulation requirements of current legislation for this type of by-products and will incorporate all relevant legislation for renewable energy, industrial waste use and organic fertilizers.

2.1.2.5. Actors involved and roles

For the successful implementation of this technology, there is a collaboration of four partners who combine their knowledge in different fields such as technological process and business management including:

Regional Association of Health Protection Pigs Nº 2 of Ejea de los Caballeros. Its aim is to give support to the pig farm sector to ensure the health of farms according to the health care legislation. It also performs the function of manure management center.

Pural is a company located in Almazán (Soria) and whose activity is focused on the management and valorization of agro-industrial waste. The company integrates innovative and sustainable technologies with the objective of taking advantage of the synergies between the processes and the organic residues. The result is the valorization of the waste and its conversion into a resource. This is done through an innovative concept in Europe that consists in the integration of render and biogas plants.

Cartif is a horizontal technology center, it is specialized in providing comprehensive solutions for businesses. Cartif works on projects of applied research and technology development in five business areas: energy and environment, industry, construction and infrastructure, agri-food and health and quality of life. It is currently a research center of reference in Europe in the fields of intelligent cities and the environment.

Oleofat Trader S.L. is a company specialized in the treatment and transformation of by-products and oleaginous waste destined to various industrial sectors, preferably dedicated to the manufacture of sustainable biofuels. It has facilities and laboratories equipped with advanced technology, prepared for the research and development of new processes in order to achieve other by-products with a high value. Specifically, this company is aimed to develop new techniques in the treatment of animal fat for its conversion into biodiesel in accordance with EN 14214.

2.1.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.2. Fish byproduct

As well as meat byproduct, fish byproducts derived from the processing and preparation of food such as backbone, head, tail, skin, entrails and fins have high levels of nutrients. In general, fish waste or byproducts contain high-quality proteins, essential amino acids, high levels of fat-soluble vitamins (A and D), and macro- and micro-essential minerals (iodine, magnesium, phosphorus and selenium). Therefore, the extraction of bioactive compounds is one of the most feasible options for the use of byproducts.

The use of processed animal proteins and enzymes in animal feed has several advantages compared to currently used plant proteins, since feed ingredients derived from plants may contain anti-nutrients and allergenic proteins.

As an example of good practices, it is described one of the European Strategies Leader that makes enzymatic modifications of fish processing waste to allow their use in subsequent chemical and biotechnological processes with high industrial interest.

2.2.1. Bio-macromolecules from municipal solid biowaste fractions and fish waste for high added value applications.

The DAFIA Project [5] aims to explore the conversion path municipal solid waste (MSW) as well as marine rest raw material (MRRM) coming from the fish processing industries in order to obtain high added value products, i.e. flame retardants, edible/barrier coatings and chemical

building blocks (dicarboxylic acids and diamine) to produce polyamides and polyesters for a wide range industrial applications. The simultaneous exploitation of the two feedstocks, such as Municipal solid waste (MSW) and marine rest raw materials (MRRM) from the fish processing industries, will create synergies in developing methods to turn fish skin and viscera, into profitable products. Based on potential commercial value and the technical feasibility which includes new microbial strains and processes for conversion of major feedstock fractions, enzymatic and chemical modifications of components isolated from the feedstock or produced in microbial processes, different value-chains and products will be explored and selected.

2.2.1.1. Market readiness

The technology has not been validated in business environment yet, but this will be achieved throughout this pilot case (TRL5).

2.2.1.2. Innovation level

Various technologies have been used to isolate the expected products from both feedstocks, such as nucleic acid, gelatin etc. Strains of bacteria will produce the desired bio-monomers (1,5-pentanediamine, muconic acid and adipic acid) from MSW hydrolysates. Also, components such as gelatine were used to develop different biobased flame retardants and they have been compounded in commercial polyamides including bio-polyamides. Furthermore, commercial gelatine developed edible and barrier coatings [6].

2.2.1.3. Environmental added-value

From the high added value products extracted from the MSW and MRRM, new bio-polyamides flame retardant compounds suitable for automotive industry, fish gelatine-based active, edible and barrier coatings for application on food and packaging and polyamides/polyesters with improved adhesion properties to metal and glass will be developed. However, there are any indications on positive potential environmental impacts that are related to the specific technology.

2.2.1.4. Fulfilment of legal requirements

The entire project will meet all legal requirements of current legislation for its implementation.

2.2.1.5. Actors involved and roles

Dafia's list of partners consist of many companies each working in their field.

AIMPLAS' fields of work are related to technological research and development on thermoplastic and thermosetting plastic materials & products, its transformation processes and their recyclability and sustainability.

SINTEF Fisheries and Aquaculture (SFA) represents technological expertise and industry knowledge in the utilization of renewable marine resources. SINTEF's materials and chemistry main research fields are Materials and Nanotechnology, Biotechnology and Nanomedicine, Sustainable Energy Technology, Oil and Gas Process Technology, Industrial Process Technology, Environmental Technology.

The Novo Nordisk Foundation Center for Biosustainability (CfB) is a research and innovation center at DTU focusing on products that can be produced using bacteria, yeasts, and mammalian cells. As the largest fundamental research organization in Europe, CNRS is involved in all fields of knowledge. Interdisciplinary programs and actions offer a gateway into new domains of scientific investigation and enable CNRS to address the needs of society.

Nutrimar is expanding to a new food grade production plant with vision to produce novel products from rest raw materials. It also aims to utilize the rest raw material from the salmon farming industry to ensure the optimal use of the natural resource.

IRIS is an advanced engineering company that specializes in process monitoring and control, and process optimisation.

Biotrend provides advanced bioprocess development, optimisation and scale-up services aiming at the production of biobased chemicals, materials and fuels from renewable raw materials. Further, biotrend actively participate in collaborative research projects in the fields of the bioeconomy and marine biotechnology.

DLab is a private company that promotes its own research and development as well as solving problems brought by external clients. Its expertise is in the fields of plastics, polymers, materials and organic chemistry.

Mine Colours is a family company with large experience in production of petrol-based plastic compounds for several industrial sectors. Its business is to develop new plastic grades suitable for specific needs.

BBEU (www.bbeu.org) is a flexible and diversified pilot plant for the development and scale up of new, biobased and sustainable processes. It is capable of development of new bioprocesses and the optimization of existing processes. The company mission is to provide clients with a holistic view of feedstock, technology, policy and market development across the bioeconomy, enabling them to make informed business decisions and develop sustainable business strategies.

2.2.1.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.2.2. Fish Waste Bio-Products: Its application in Organic Farming

A plant biostimulant is any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content [7]. The use of bio-stimulants to promote plant growth has increased in recent years in Europe being the value of the European market range around USD 1.5-2 billion in 2022.

Biostimulants are not fertilizers as they do not provide nutrients directly to plants, but they can facilitate the acquisition of nutrients by supporting metabolic processes in soil and plants. Among other beneficial effects, biostimulants can increase nutrient use efficiency so that farmers receive a better return on their investment in fertilisers.

Fish protein hydrolysates are also used as biostimulants and are ordinarily derived from fish skins and other by-products such as heads, muscle, viscera, bone, frames and roe.

2.2.2.1. Market readiness

Table 1 shows some of the commercially produced plant biostimulants from different sources that are currently available on the market.

Table 1. Available plant biostimulants, their composition and application strategies. [8]

Biostimulant	Origin	Active Compounds	Application Methods	Plant	Main Activity
C Fish	White fish/mixed fish composition autolysates and hydrolysates	Peptides, amino acids	Foliar, irrigation, pre-planting	Vegetables, fruits	Increase plant's resistance to insect pressure, disease and heat or drought stress

2.2.2.2. Innovation level

In organic agriculture, the use of chemical fertilizers and pesticides is very limited, so different suitable natural products are needed to guarantee a correct productivity of the crops.

2.2.2.3. Environmental added-value

In organic agriculture, the use of chemical fertilizers and pesticides is very limited, so different suitable natural products are needed to guarantee a correct productivity of the crops.

2.2.2.4. Fulfilment of legal requirements

The new Fertilizing Products Regulation (FPR) (EU) 2019/1009 was published on 25 June 2019. The European Union is the first governing body in the world to recognize plant biostimulants as a distinct category of agricultural inputs. From 16 July 2022, biostimulants will bear the "CE" mark, which will allow free market access to all EU Member States.

2.2.2.5. Actors involved and roles

C-fish Fresh & Frozen Fish By Products, Ireland

Symbio,BioBooster Fish Hydrolysate, Uk

2.2.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.3. Spend coffee waste

Traditionally, the waste from the coffee grounds have been used in a small scale as compost and fertilizers in the gardening sector since they represent a contribution of organic matter to improve drainage and retain moisture, in addition to aerating the substrate.

Through new innovative solutions, the sustainable production of chemicals and biological materials from this hitherto largely unexplored raw material can be achieved.

As an innovative strategy, it is presented the experience of the Jacobs Douwe Egberts plant in the Netherlands, which uses waste coffee grounds as biofuel to produce the steam it needs for its own production process.

2.3.1. Turning coffee byproduct into green energy.

This particular joint venture is based on a circuit circular loop where Jacobs Douwe Egberts and Veolia [9] came up with an idea in order to use spend coffee grounds from the plant's production to produce steam. The Jacobs Douwe (JDE) plant is located in Joure, in the Netherlands, where coffee grounds are being used as biofuels to produce the energy needed for its operation.

2.3.1.1. Market readiness

The market readiness remains in a high level considering that this initiative is being implemented as a short circuit circular loop in Jacobs Douwe Egberts (JDE) plant located in Joure, in the Netherlands, and uses of industrial coffee grounds as biofuel to produce the energy needed for its operation.

2.3.1.2. Innovation level

The main idea is to replace natural gas with spent coffee grounds to generate an important amount of steam necessary for the production of the soluble coffee. Instead of being sent to landfill the waste from the coffee beans produce a large amount of residue which is now used to generate steam to operate the plant as a part of a biomass boiler.

2.3.1.3. Environmental added-value

This biomass boiler is fueled only by spent coffee grounds helping JDE vision to optimize the energy invoice and reduce its carbon footprint at the same time. The boiler helped to achieve an approximately 70% reduction in JDE's annual emissions which means that 14.000 tons of CO_2 were avoided annually, plus one million euros were saved on its energy bill.

2.3.1.4. Fulfilment of legal requirements

This technology is already operating in JDE plant located in a European country, following the existing legislation in order to obtain the appropriate permissions.

2.3.1.5. Actors involved and roles

Jacobs Douwe Egberts (JDE) is a Dutch company that owns numerous beverage brands (coffee, tea and hot chocolate).

2.3.1.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this process can be potentially implemented in every EU country where this type of industrial coffee grounds are produced. The feedstock that arises from the retail locations cannot be dealt with and nor can the domestic waste from households.

2.3.2. Bio-components from spent coffee grounds

Coffee is one of the largest traded commodities in the world. This represents a large amount of residues from this industry which corresponds to an annual amount of about 6 million tons

worldwide [10]. Valorization from SCGs can include aromas, natural flavours, carotenoids, food ingredients, nutraceuticals, food preservatives and use in skincare products.

2.3.2.1. Market readiness

SCGs are formed during the extraction of coffee powder with hot water to produce a coffee beverage and during the production of instant coffee preparations. Spent coffee grounds can be collected from HORECA (Hotels/Restaurants/Cafe) and household use including coffee pods.

Feasible bio-applications from spent coffee grounds are:

- carotenoids by fermentation of SCGs hydrolysates [11]. Carotenoids are organic pigments that are produced by plants and algae, as well as several bacteria and fungi. Generally, those compounds are the most widely distributed class of pigments in nature, displaying yellow, orange or red color. Carotenoids are commercially used as food colorants, animal feed supplements and, more recently, as nutraceuticals for cosmetic and pharmaceutical purposes.
- food ingredient as antioxidant dietary fiber for bakery products [12].
- nutraceuticals as inflammatory diseases [13].
- food preservative as antioxidant properties inhibiting lipid oxidation [11].
- skincare products. An emulsion containing 35% of oil extracted from spent coffee grounds presented promising characteristics as a sunscreen [14].
- aromas and natural flavours [15].

2.3.2.2. Innovation level

The biotechnological production of carotenoids becomes industrially feasible if the cost of the process is minimized by the utilization of cheap carbon substrates such as waste products of agriculture or food industry. Carotenoids can be produced by fermentation of spent coffee grounds hydrolysates by the yeast Sporobolomyces roseus.

Aromatic flavor components (diacetyl and acetaldehyde) are recovered from an aroma stream generated by thermal hydrolysis of a partially extracted roasted and ground coffee. The flavor can be used as a natural ingredient.

2.3.2.3. Environmental added-value

In Europe, spent coffee grounds are currently being incinerated or disposed of in landfills [4]. The environmental impact of disposing of spent coffee grounds is undesirable. In addition, the large amount of tons of disposed spent coffee ground represents an important economic resource.

2.3.2.4. Fulfilment of legal requirements

Limitations on the use of coffee by-products are related to their caffeine content. Results published to date suggest that caffeine content does not need to be considered a safety concern in the application of coffee by-products as food ingredients [3]. The caffeine content in foods formulated with coffee by-products should be below the European Food Safety Authority (EFSA) safety level for daily caffeine consumption of 400 mg for the general population and 200 mg for lactating women.

2.3.2.5. Actors involved and roles

Spent coffee grounds can be collected from HORECA (Hotels/Restaurants/Cafe) and household use including coffee pods.

2.3.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

The main barrier for the use of SCGs is the implementation of selective collection from HoReCa and households.

2.4. Source separated biowaste

This biowaste fraction consists of leftovers from the preparation of food or the handling and processing of food products, leftovers from food, spoiled food and food surpluses that have not been placed on the market or consumed (separated from their packaging).

There are currently several innovative solutions to transform this organic matter into biobased products. from packaging of pure cellulose (biomaterials) which do not require the addition of fossil fuels, high-performance, low-impurity intermediate chemicals of high industrial interest for the production of solvents, adhesives, polyols for polyurethane and PHA among others; soluble bio-mechanical substances can also be obtained that will be used as additives for anaerobic fermentation reactors by improving the economy and the environmental impact of current fermentation technology. It also presents the experience of a pilot project for the production of insect proteins from biowaste as a sustainable alternative to fish and soya meal for animal feed.

2.4.1. Conversion of biowaste into pure bio-nanocellulose form by a bacterial fermentation process (SCOBY Packaging)

SCOBY Packaging [16] is weaved through a biological process that turns biowaste into a bio-material film. Polish designer Roza Janusz has found a way to create fully biodegradable food packaging applying a microbial fermentation process that results in multiple layers of a wrapping membrane. To produce this material, she started off with a Symbiotic Culture Of Bacteria and Yeast (SCOBY) fed with organic substances from agricultural and food industrial biowastes. Although, that was an early work and an inspiration not suitable for mass production yet. MakeGrowLab develops process of biomass growth that is still based on waste and does not require the addition of fossil-fuels or other non-biodegradable substances, and the technology is during first pilot projects with customers. Patenting of the technology is in process (Dec 2019).

2.4.1.1. Market readiness

SCOBY packaging developed by MakeGrowLab is made entirely from local agricultural and food industrial wastes: liquid biowaste from beer, wine, juice industry and non-edible vegetable wastes are converted into pulp materials and sheets (TRL 6-7 in 2019). Biowaste used does not have a market price, the cost of feedstock is determined by transportation cost.

2.4.1.2. Innovation level

SCOBY packaging is completely compostable, flexible, durable, insoluble in water and impermeable to water, has a shelf life of two years, generates an oxygen barrier and a microbial barrier which keeps foods fresh, 100% free from (micro)plastics, e.g. PLA. From bags to bowls, from sachets to trays, the material can be used in various shapes for all kinds of packaging and wrapping that might normally be done with conventional plastic. It is suitable to store dry or semi-dry foods, from nuts to salads. Thanks to the relatively simple proprietary technology, the material can also be grown by agricultural producers themselves to wrap their products and bring them to market with zero waste.

2.4.1.3. Environmental added-value

Biowaste converted into biomaterial. SCOBY packaging offers a sustainable solution to the single-use plastic problem. It is fully compostable like household plant wastes (or even edible) and thus can serve as a fertiliser material after disposal.

2.4.1.4. Fulfilment of legal requirements

The SCOBY packaging solution meets all the packaging and packaging waste legislative requirements for bio-material following the European Strategy for Plastics in a Circular Economy [17] as well.

2.4.1.5. Actors involved and roles

MakeGrowLab [18], an eco-friendly team of designers and scientists has created a revolutionary, sustainable, compostable and even edible zero-waste packaging material. MakeGrowLab consults, designs and produces eco-materials for mission-driven companies.

2.4.1.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.4.2. Chemical building blocks from versatile MSW biorefinery

PERCAL [19] exploits Municipal Solid Waste (MSW) as feedstock to develop intermediate chemical products at high yield and low impurity level with huge industrial interest. These will be complementary to the bioethanol (current PERSEO Bioethanol Technology [20]), to achieve a cascade valorisation of the MSW components:

Lactic acid (LA) to produce: 1) Eco-friendly ethyl lactate solvents by reactive distillation from lactic acid & bio-ethanol to be used in cleaning products and inks and 2) hot-melt adhesives for cardboard and other non-food applications in combination with maleic anhydride by reactive extrusion.

Succinic acid (SA) as an intermediate building blocks to production of polyols for the polyurethane industry.

Biosurfactants by chemical and/or microbiological modification of protein and lipid fraction from remaining fraction of MSW fermentation.

Among the main achievements of this project is the achievement of fermentation level up to 85% of potential fermentable sugars contained in heterogeneous organic MSW, producing lactic acid with more than 90% purity and succinic acid with more than 99 % purity.

2.4.2.1. Market readiness

PERCAL is a technological solution that will be exploited after the end of this project by the end of 2020. Therefore, its market readiness is not at business level. However, within the project activities this technological process has been tested and verified at least at demonstration in a smaller scale.

2.4.2.2. Innovation level

The PERCAL project is expanding the circular economy by developing novel solutions for transforming the organic part of municipal solid waste (MSW). This process leads to four main innovations; new enzymatic cocktails to maximize hydrolysis of fermentable organic matter

with low inhibitors production; high yield, specific and robust strains for each selected acid; extraction of fermentation by-products acting as inhibitors to succinic acid production via novel membrane electrolysis and optimised simultaneous saccharification and fermentation for lactic acid production followed by a downstream separation process. These should minimise issues of heterogeneous MSW composition.

2.4.2.3. Environmental added-value

PERCAL intends to improve the yield of intermediate extraction/recovery from the organic content of MSW by 20% with respect to state-of-the-art or exceed 80% yield of intermediates. It will also validate removal of inhibitors to a level where it allows cost-effective downstream processing, comparable to that obtained from lignocellulosic biomass. The difference in yield between them should not exceed 10 percent. Therefore, this solution could offer a number of environmental and socially important impacts, as it will reduce the environmental impact of production by using environmentally friendly technologies. It will also contribute significantly to jobs in green chemistry in coming years.

2.4.2.4. Fulfilment of legal requirements

The use of biofuels made from biomass provides a renewable alternative to fossil fuels in the EU's transport sector [21]. These strategies are crucial to help achieve the economic transformation needed and broader sustainable development goals, as well as move towards the long-term goal set by the Paris Agreement [22].

2.4.2.5. Actors involved and roles

The list of partners involved in the project:

IMECAL: The R&D line of production technology for second generation bioethanol, has developed a biotechnological patented technology for obtaining bioethanol from Organic Municipal Waste.

AIMPLAS' fields of work are related to technological R&D on thermoplastic and thermosetting plastic materials & products, its transformation processes and their recyclability and sustainability.

ATB: The Institute's mission is to develop sustainable and highly innovative technologies for the resource efficient utilization of biological systems to produce food, raw materials and energy.

Agricultural University of Athens: The Department of Food Science and Human Nutrition (DFSHN) of AUA promotes the existing knowledge on Food Science and Human Nutrition through research and development programs.

The principal research strategy at CMET aims at understanding phenomena of microbial ecology in order to manage the vast metabolic capabilities of complex microbial communities to solve practical problems.

The National Renewable Energy Centre (CENER) is a technology centre specialised in applied research, and the development and promotion of renewable energies. It is highly rated and has acknowledged national and international prestige.

TBWR`s focus is on applied research only especially in cooperation with industry partners. Thematic fields of R&D activities are in general mobility, energy & renewables, construction and water management.

VISUM is an optical engineering company from Dublin that specializes in the development and commercialization of Near Infrared Spectroscopy (NIRS)-based portable and inline analyzers and measurement systems for process monitoring.

YPAREX: The Compound Company is headquartered in Enschede, the Netherlands, next to its main production facilities, warehouses and quality lab. The Compound Company has 2 product brands: Yparex® and EcoForte®. Yparex® is a product range of extrudable adhesive resins and EcoForte® is a product range of customized thermoplastic compounds.

Hayat Kimya was established in 1937 as a textile trading company. Company has entered the FMCG industry in 1987. Today, with 5200 employees Hayat Kimya is one of the largest FMCG (household cleaning & personal care, baby–care & feminine hygiene, and paper tissue & towels).

Covestro is a world-leading supplier of high-performance polymer materials for key industries. Business activities are focused on the manufacture of high-tech polymer materials and the development of innovative solutions for products used in many areas of daily life.

EXERGY: We are unique in our ability to offer vertically integrated skills in a range of sustainable energy technologies. Exergy can be involved at every stage: from project design and development, through planning and financing, engineering and construction to operation.

2.4.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU *country.*

2.4.3. RESources from URban Biowaste

RES URBIS [23] aims at making it possible to convert several types of urban biowaste into valuable biobased products, in an integrated single biowaste biorefinery and by using one main technology chain. This goal will be pursued through:

- collection and analysis of data on urban biowaste production and present management systems in four territorial clusters that have been selected in different countries and have different characteristics.
- well-targeted experimental activity to solve a number of open technical issues (both process- and product-related), by using the appropriate combination of innovative and catalogue-proven technologies.

During the whole project the following main results were achieved:

- Long-term PHA production is feasible at pilot scale, starting from true organic waste: Two pilot plants were continuously operated to produce PHA. One plant was fed with fruit processing effluents and the other one with a mixture of organic fraction of municipal solid waste and excess sludge from urban wastewater treatment. In both plants, the PHBV copolymer (3-hydroxybutyric and 3-hydroxyvaleric monomers) was produced, with HV content ranging between 10-20% w/w, depending on feedstock composition and operating conditions. In parallel, the key upstream step, i.e. production and concentration of PHA precursors (volatile fatty acids) were improved.
- 3 generations of batches of PHA containing biomass were prepared (PHA > 30 kg) for PHA extraction and downstream processing. A set of different extraction methods was investigated using environmentally friendly inorganic reagents or organic solvents (including biosolvents generated in the project). The former was developed up to pilot scale. PHA with more than 95% purity was obtained, using reduced reagent quantities compared to initial protocols. The polymer remains white after melting test.
- PHA applications. PHBV-biomass samples were successfully extracted, processed through electrospinning, and characterised (mechanical and barrier properties) in comparison to commercial PHBV. In this way, applications as interlayer film, and "adjacent" adhesive market, have shown high market potential. Also, PHA was compounded and used for commodity films and durable goods, 90% biobased and with acceptable mechanical properties. Biocomposite with fibres from park/garden waste were also developed as well as PHA-rich biomass was successfully tested as C-releasing material for groundwater remediation.
- Presence of microcontaminants: Polycyclic aromatic hydrocarbons (PAHs), polychlorobiphenyls (PCBs) and heavy metals, were analysed in raw materials (PHA-rich biomass) and in extracted PHA samples (by using many extraction methods). Overall, it was shown that contaminant concentration meets present regulatory standards for several plastic applications.

2.4.3.1. Market readiness

During the experimental activity, it will be implemented a market analysis within several economic scenarios and business models for full exploitation of biobased products including a path forward to fill regulatory gaps. The Technology Readiness Level lays between 5 and 6.

A pilot biorefinery located in Treviso, close to Venice, Italy uses organic carbon in source-sorted municipal waste collection and sludge from wastewater treatment plants. The other in Lisbon, Portugal uses different organic wastes from food processing, particularly from fruit juice extraction available close by. The main conclusion was that the process is stable and robust enough to cope with the fact that the waste is not very stable and has certain heterogeneity, and it produces a good quality polymer.

2.4.3.2. Innovation level

By the end of the whole RES URBIS technology chain to convert urban organic waste into PHA-based bioplastics, the value chain was shown to be flexible enough to cope with different waste management systems, to be easily integrated with existing anaerobic digestion plants, and to offer economic gain while maintaining PHA at an affordable price for the tested product portfolio (3 €/kg). Provided that an intermediate demo-scale action is performed, the RES URBIS value chain could affect most waste management systems for territorial clusters of more than 500.000 inhabitants.

2.4.3.3. Environmental added-value

A complete LCA was performed that compared 6 potential scenarios for the management of urban organic waste, where the baseline was current management. The LCA was largely built on data collected and generated within the project, e.g the calculations made to extrapolate an inventory of a full-scale version of the RES URBIS biorefinery. The results showed that the RES URBIS biorefinery has potential environmental benefits.

2.4.3.4. Fulfilment of legal requirements

The regulatory framework takes into account the drivers or the barriers individuated. The EU regulation on waste sector has recently been updated to conform to new challenges of the circular economy. The new regulation opens good perspective for proposed solution, considering that "end of waste" criteria are defined at least at national level. Also, it was found that being polymers, PHA are exempted from REACH [24] and ECHA [25] registration, unless impurities are more than 2% and their composition is not known.

2.4.3.5. Actors involved and roles

The partners of the project are academic, private companies, public authorities and industrial associations. The involvement of these different roles in this experimental process offered a

complementarity which is needed for this kind of initiatives. Namely the partner involved are: University of Roma "La Sapienza", Technical University of Denmark, New University of Lisbon, Biotrend (SME), SABIOMATERIALS (SME), University Ca Foscari of Venice, University of Verona, BioInicia (SME), CNR – IRSA, University of Barcelona, University of Bologna, Provincia Autonoma di Trento, Mi-Plast (SME), Agua do Tejo Atlantico (Company), InnoEXC Partners (SME), University of South Wales, National Institute for work safety, Barcelona Metropolitan Area, Biobased and Biodegradable Industries Association and Institute National de la Recherche Agronomique.

2.4.3.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this process can be potentially implemented in every EU country.

2.4.4. LIFECAB - Biogas and digestate with controlled ammonia content by a virtuous biowaste cycle with integrated bio&chemical processes

LIFECAB [26] introduces a new process to treat municipal biowaste (MBW) and produce soluble biorganic substances (SBO). These substances will be used as additives for anaerobic fermentation reactors to improve the economy and environmental impact of the current fermentation technology. This is achieved by pursuing three main objectives:

- validating the soluble biorganic substances production process in real operational conditions;
- validating the new soluble biorganic substances assisted anaerobic fermentation process;
- demonstrating a new business model, which allows the valorization of biowastes through integrated biochemical and chemical processes in real operational environment with reduced entrepreneurial risk.

2.4.4.1. Market readiness

LIFECAB is a pilot project that aims to validate at TRL7 a previous research undertaken by the University of Torino in cooperation with Acea Pinerolese Spa located in Pinerolo.

2.4.4.2. Innovation level

This biowaste treatment cycle will operate through the process of hydrolysis of fermented MBW in water. Municipal biowaste which have been composted are hydrolysed into yield soluble bio-baste substances. This procedure increases biogas quality and productivity and contribute to anaerobic fermentation improvement. In addition, a new business model for biowaste valorization is being demonstrated in order for the first MBW refinery to rise and produce biogas with a more eco-friendly and cost-effective approach. The results of the

project will contribute to the implementation of the requirements foreseen by the Circular Economy Action Plan and the Roadmap to a Resource Efficient Europe.

2.4.4.3. Environmental added-value

The main outcome from this project is to achieve a production of biobased products from various EU municipal biowastes, through the process of hydrolysis. Other expected results include a new anaerobic fermentation process with a soluble biobased substance (SBO) addition to produce digestate with very low ammonia content. Furthermore, a production of 50 tonnes of SBO is wanted as an additive in anaerobic digestion. The expected yearly outputs from an MBW plant treating are 105 MBW tonnes/year of 8.6 Mm3 of biogas, 6000 tonnes of digestate, 5400 tonnes of compost, and 1000 tonnes of SBO from hydrolysis.

2.4.4.4. Fulfilment of legal requirements

The results of the project will contribute to the implementation of the requirements foreseen by the new Circular Economy Action Plan [17] which is part of the Green Deal [27] and the Roadmap to a Resource Efficient Europe [28].

2.4.4.5. Actors involved and roles

Several partners are taking part to this project, each contributing to their field. There three partners from Italy Hydro System Treatment, ACEA, University of Turin and POOL. The first, being the coordinator, is in charge for prototype facilities realization (design and construction of prototypes). ACEA contributes to the collection of regional biowaste, SBO production and assisted anaerobic fermentation. University of Turin operates as an operational assistance and analytical service for ACEA. POOL works as a full time assistance for project accounting, report preparation, management and for the partners coordination. Furthermore, other partners as Agricultural University of Athens and Cyprus University of Technology are both in the process of operational assistance.

2.4.4.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.4.5. LIFE Waste2Protein - Pilot plant for insect protein production from biowaste as sustainable alternative to fish and soy meal for animal feed

The LIFE Waste2protein project [29] aims to use organic residues as a main resource for insect protein production, from larvae of the Black Soldier Flies (BSF). This is a very sustainable and environmentally friendly solution in the feed stuff industry. The project aims to create a circular economy model by using organic residues to produce valuable protein based on insect base,

which creates new value chains and economic possibilities. This will be succeeded by installing a pilot plant for insect protein production at large scale with an annual production capacity by 2022 of 730 tonnes of insect protein, 3650 tonnes of substrate for fertilisers and 365 tonnes of high-value fat from 7 300 tonnes of biowaste.

2.4.5.1. Market readiness

The project introduces a technological approach which is basically in testing phase. The pilot plant practically will operate in large scale capacity although the process is not a proven in the market.

2.4.5.2. Innovation level

LIFE Waste2protein project will assist the innovative research by optimizing the quality and quantity of the protein in order to achieve a high level of system automatisation.

2.4.5.3. Environmental added-value

Multiple results are expected during the project. One of the environmental benefits that are expected to occur is the reduction of CO_2 emissions by 70% compared to fish meal and 50% compared to soy meal, plus an 80% reduction of water consumption. Speaking of rates, a 40% reduction in greenhouse gases will happen compared to composting biowaste. On an economical aspect, there will be an 80% reduction in costs, compared to conventional methods, for industrial production of 1 tonne of insect protein.

2.4.5.4. Fulfilment of legal requirements

The project contributes to the implementation of waste legislation including the Waste Framework Directive [30], the Circular Economy Package [31] and the Landfill Directive [32]. Furthermore, it contributes to the Common Fisheries Policy [33], the EU action plan against antimicrobial resistance [34], and the long term strategy (2050) for low-carbon economy roadmap [35].

2.4.5.5. Actors involved and roles

AviComp Controls is a leading independent engineering contractor and a provider of superior Engineering consultancy Services. The Company is located in Leipzig. Their expertise is on developing and commissioning industrial control systems.

2.4.5.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.4.6. Waste2Bio – Development and demonstration of an innovative method for converting waste into bioethanol

The principal idea of WASTE2BIO [36] is to develop a more sustainable and efficient alternative to the current methods by producing bioethanol from biodegradable materials present in the MSW and to process the residual feedstock into biogas using anaerobic digestion.

2.4.6.1. Market readiness

This project incorporates the technological progress for the design, development, testing and optimisation of an innovative pilot-scale plant, for the production of bioethanol from biowaste via bioconversion.

2.4.6.2. Innovation level

The production of bioethanol stemming from organic fraction of MSW is a significantly environmentally friendly method of processing with MSW compared to conventional methods. The recovered energy which is contained from organic waste is transformed into bioethanol and bioenergy is a massive advance in waste treatment and disposal of MSW.

Partners IMECAL and CIEMAT will develop a new technology to treat the organic matter contained in the MSW. This is used to produce organic fibers rich in cellulose an hemicellulose which will be converted into bioethanol. The remaining amount of organic material in the feedstock can be transformed into biogas throughout anaerobic digestion which can be used as a fuel for production of electricity and heat.

2.4.6.3. Environmental added-value

The project lasted 4 years during which several results were occurred. First of all, it successfully built and operated the pilot plant that was proposed managing to produce bioethanol from pre-dried source separated biowaste. It achieved a maximum theoretical bioethanol yield ranging from 72.56% to 77.34% efficiency. Over 60 tons of biowaste did not end up in landfill but instead it was dried, reducing its volume and weight by 70, and used as feedstock for the bioconversion unit. Furthermore, the bioethanol met technical requirements for its production, making it suitable for use as a fuel additive.

2.4.6.4. Fulfilment of legal requirements

The legal requirements are related to meeting the targets set out in relevant EU directives, such as the Landfill Directive (1999/31/EEC) [32], the Directive on the Promotion of Renewable Electricity (2001/77/EC) [37], and the Biofuels Directive (2003/30/EC) [38], thus demonstrating in concrete terms how EU legislation governing waste management and biofuel production can be implemented.

2.4.6.5. Actors involved and roles

There are 4 partners who contribute to the development of this technology, each working on its field, including the coordinator.

MECAL is involved in chemical, petrochemical, bioprocess equipment design, manufacturing and lignocellulosic bioprocess design, from laboratory to engineering design and manufacturing. IMECAL are the developers of the innovative PERSEO Bioethanol®: Process patented technology for obtaining bioethanol from Organic Municipal Waste.

The Biotechnology Processes Unit at IMDEA Energy has as its main domain anaerobic digestion of organic waste to produce either biogas or volatile fatty acids. Particularly the nutritional demands of the facultative and methanogenic microorganisms degrading waste substrates.

EXERGY's field is about chemical and environmental process design, simulation (AspenOne/ SuperPro) and optimisation of process facilities, as well the development of basic engineering for chemical processes. Exergy also have extensive knowledge in the scaling-up of biochemical and chemical processes, and experience in waste processing projects to obtain valuable bioenergy products.

CIEMAT's Liquid Biofuels Unit have an extensive background in the development of processes and technologies to produce bioethanol from lignocellulosic biomass, working on the main step of the global process: pretreatment, enzymatic hydrolysis and fermentation.

2.4.6.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.5. Used cooked oils

Fats and oils are an energy source of fatty acids. Its lipid nature and its high energy density allow to obtain yields twice those reached in carbohydrate-based substrates. Its chemical transformation allows obtaining biodegradable biopolymers (PHA) or even bioenergetic substances as biofuels. The proposed innovative solutions have developed an integrated and sustainable system for the recovery of waste oils.

2.5.1. Production of PHA (polyhydroxyalkanoates) using waste cooking oil by HYDAL fermentation process

HYDAL is a technology for producing fully biodegradable and biocompatible PHA biopolymers from waste cooking oil. First step is microbial fermentation, where bacteria "consume" waste cooking oil and transform it into granules of polyhydroxyalkanoates (PHA) stored inside the bacterial cell. This process is commonly called the upstream phase. The second step is the isolation of polymer from microbial cells, it is called the downstream process which involves the disintegration of microbial cells from which PHA granules are released. The obtained polymer in the form of a powder may be processed into granules.

PHA family of biopolymers is unique to polymers from renewable resources, as it comprises the only group of polymers converted from raw materials into their final form directly by microorganisms. The biopolymers produced this way can serve as food for other microorganisms, therefore they can be biodegraded. Polyhydroxybutyrate (PHB), a type of PHA is similar in its material properties to polypropylene (PP) and polystyrene (PS), has a good resistance to moisture and aroma barrier properties and has a unique position in the PHA family, as it is completely biodegradable and also biocompatible, it biodegrades in wastewater treatment plant within several days, in the open environment up to several dozen days. Currently, the PHB biopolymer's application is multifaceted, it can replace synthetic plastics in meaningful applications or microplastics (e.g. in the cosmetics industry or medicine). HYDAL feedstock is waste cooking oil of almost any quality, so, unlike the competitors, the technology does not use crops or other feedstock produced on agricultural land. The greatest asset of the HYDAL technology is that it can significantly contribute to reducing of pollution caused by plastics and microplastics and solves in certain way, the problem of waste cooking oil utilization as well.

2.5.1.1. Market readiness

The technology (TRL9) transforms waste cooking oil into a high-value biomaterial polymer by using a bacterial fermentation process. HYDAL biotechnology, as the first in the world on the industrial scale, uses waste cooking oil (mostly a mixture of different plant oils as rapeseed and sunflower oil) to produce a raw material for the production of biodegradable microbeads, UV filter in sunscreens or bioplastics.

2.5.1.2. Innovation level

The innovation level lays into the process innovation which introduces the desired biopolymer – P3HB: poly-3-hydroxybutyrate or PHBV: poly(3-hydroxybutyrate-co-3-hydroxyvalerate) – has purity higher than 99% and high molecular weight. The product is mixed with additives for stabilization. Each blend is unique for the final product (cosmetics, medicine, agricultural products, etc.). From 1 liter of waste cooking oil 0.7 kg of natural polymer of an average price

15 EUR/kg can be produced. In 2019 the company has not had the possibility yet to establish their own production facility for this final biopolymer. In 2019 the suitability of an other waste material, sludge palm oil was verified by the company's research activity for PHA production. [39].

2.5.1.3. Environmental added-value

Biopolymer PHB produced by HYDAL biotechnology is 100% biocompatible and biodegradable, i.e. it completely decomposes in the soil, water and the seas. It neither harms the environment nor humans. The technology solves the problem of waste cooking oil utilization, and at the same time requires less water and energy compared to PHB production from sugar beet, potato, wheat or corn. Clear end of life cycle of products based on PHA produced by HYDAL biotechnology can significantly contribute to the reduction of environmental damage caused by microplastics and plastics.

2.5.1.4. Fulfilment of legal requirements

Legislation related to the collection of cooking oil waste from citizens (this will be modified in 2020); standards regulating the quality requirements for cosmetics.

2.5.1.5. Actors involved and roles

A Czech knowledge-based company, NAFIGATE Corporation (founded in 2011) has developed biotechnology HYDAL, taking care of transitioning the technology from the laboratories of the research institutions to an industrial scale, up to the final commercialisation phase. HYDAL is an upcycling technology inspired by natural processes.

2.5.1.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.5.2. LIFE BIOSEVILLE - New biofuel production technology to recover used frying oils and power the Seville's urban bus fleet

Various vegetable oils and animal fats are used in the production of biodiesel which offers a more environmentally friendly solution comparing to mineral diesel. There are a lot of advantages derived from these biofuels but their production costs are still significant. Producing biodiesel from used cooking oil has fewer costs as the raw material is already available in the form of waste product. Furthermore, exploiting used cooking oils for the production of biodiesel also avoids costs associated either with their management and appropriate disposal, or even their inappropriate disposal. The LIFE BIOSEVILLE project [40] aimed to develop an integrated and sustainable system for the recovery and processing of

used cooking oils to produce a new, more competitive and efficient biofuel. It aimed to demonstrate the feasibility of using this biofuel in the local bus fleet in Seville to significantly reduce air pollution and greenhouse gas emissions.

2.5.2.1. Market readiness

This technology tests to find out if it is possible to produce a new, competitive and efficient biodiesel composed of methyl esters and glycerin esters from used cooking oils. Two prototypes developed and are able to produce methyl esters (reaching 91% purity) and purify glycerine (reaching 97% purity): 25m3 of the new biodiesel were produced according to European standards (EN 14214), and 2.500 litres of bio-additive (glycerine esters from purified glycerine) were obtained for use in biodiesel.

2.5.2.2. Innovation level

The project planse to construct a pilot processing plant to produce biodiesel from used cooking oils. The first of two production modules would use an innovative transesterification technology to produce methyl esters. The second would use membrane technology to produce technical grade glycerine with a high degree of purity, which it will then process with acetic acid through acid catalysis to produce glycerine esters.

2.5.2.3. Environmental added-value

The project had successful results decreasing CO_2 emissions, which were related to bus travel from 74.31 g CO_2 per liter of conventional diesel to 56.45 g CO_2 emitted per liter of biofuel, achieving also a reduction of 447.5 Kg of CO_2 emission. The project was provided around 30m3 of used cooking oil preventing their disposal in sewage treatment plants. Considering the entire life cycle of the fuel, all actions resulted to an approximately 60% reduction in overall CO_2 emissions by replacing part of the fossil fuel used in buses with a new biofuel.

2.5.2.4. Fulfilment of legal requirements

This technology contributes to meet the goals of 2030 climate and energy framework [41] includes EU-wide targets and policy objectives for the period from 2021 to 2030. In addition, it incorporates the promotion of the use of energy from renewable sources

2.5.2.5. Actors involved and roles

There are 4 partners who contribute to the development of this technology, each working on its field, including the coordinator.

University of Seville (US-AGR155). Since 2014, group AGR155 from the University of Seville has worked in the production of biofuels using industrial by-products, such as the paste generated in vegetable oil refinery plants, which is difficult to sell back in the market. The group researched on a process to use this paste as a raw material for the production of biodiesel,

which was funded by the Spanish Ministry of Education and Science (MEC) through a national plan project in the 2014 call.

Ciemat is a public excellence research body focusing on energy and environment as well as new technologies and various basic research areas. Since its creation in 1951 as Nuclear Energy Board and then renamed as Ciemat in 1986, this Spanish public research body runs technology development and research projects, which are then used to represent Spain in international forums and also for Spanish public administrations' consultancy purposes. Ciemat's main role in LIFE BIOSEVILLE, apart from developing a dissemination plan and establishing a network with other centres, it will help demonstrating improvement in the biofuel's combustion process. In addition, measuring emissions on engine test bench will help the procedure.

CARTIF is a technology centre, which specialises in applied research. Its main goal is to promote companies' technological possibilities so that they can develop new products and processes and become more competitive. CARTIF is a horizontal research centre covering a wide range of scientific disciplines, which enables us to provide companies with integral solutions. CARTIF's role in LIFE BIOSEVILLE is to optimize and operate the prototype module for the production of methyl esters and glycerine but also analyses the environmental advantages of the process.

Campo Sur Investiga is a private company, which specializes in applied technological research and aims to promote the use of natural resources for an economic and social sustainable growth.

2.5.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.6. Cellulosic rejections of MSWTP

They mainly come from industrial or urban waste treatment plants. Cellulose is currently being researched as a new resource for the production of lactic acid, a raw material for PLA (polyacetic acid), therefore, an innovative treatment process is presented that produces bioplastics from cellulose recovered from municipal sewage.

It also shows an example of an innovative strategy using cellulosic rejections from paper and pulp factories to obtain bioenergy products (biogas) as vehicle fuel.

2.6.1. Innovative bioenergy products from paper and pulp mills' sidestreams utilizing novel biogas technology

Having over 20 years of experience, EcoProtech [42] is the leading company in the field of biogas technology having established multiple references in anaerobic digestion processes. The EcoProtect Advanced Digestion (EPAD) [43], apart from being very reliable as well as a cost effective solution for sustainable waste management, is designed to produce nutrients and energy from organic waste. Multiple other organic waste fractions are suited to this particular process such as industrial sludge, biowaste, waste water treatment etc.

2.6.1.1. Market readiness

EPAD is the first biogas technology to utilize forest-based slurries from pulping process as the feedstock. The market readiness is at high level considering that EPAD is being implemented in a biogas plant in Metsä Fibre Bioproduct Mill in Äänekoski, Finland.

2.6.1.2. Innovation level

Within the scope of innovation, the main design aims to ensure maximum recycling of resources and bioenergy recovery by closed loop systems in which material and energy flows are developed in order to produce an environmentally sustainable and highly efficient process. Heat, fuel and electricity are the main products coming from the produced energy.

The process includes 7 steps, starting with the receiving of the feedstock such as biowaste, pupl and paper sludge and other municipal materials. After that the pretreatment the homogenization of the feed breaks material structure in order to maximize capacity and biogas production. The feed preparation phase includes the feed's preparation for the anaerobic digestion. Then, the main process of anaerobic digestion is taking place. Compering to other conventional processes EPAD manages to achieve savings in investment costs. The biogas produced is further processed and it can be used as fuel in vehicles.

2.6.1.3. Environmental added-value

There are various advantages stemming from EPAD technology, considering the fact that there are no emissions coming from end products or any other problems. Even more, these products are hygienic and sterile, having high nutrient recovery. Apart from that, the EPAD technology has low investment operation and maintenance cost, high biogas production rat, as the closed process gas treatment systems ensures low carbon and greenhouse emissions.

2.6.1.4. Fulfilment of legal requirements

EPAD contributes to meet the goals of 2030 climate and energy framework [29] includes EU-wide targets and policy objectives for the period from 2021 to 2030. In addition, it incorporates the promotion of the use of energy from renewable sources[1].

2.6.1.5. Actors involved and roles

EcoProtech is the leading company in the field of biogas technology and has various services which cover process design, cover feasibility studies based on their experience in biochemistry, chemical engineering and process technology.

2.6.1.6. Barriers to replication in other European countries

There is no indication that the procedure cannot be applied and replicated in other European countries, considering its impact.

2.6.2. cellu2plaLIFE+ – Demonstration of an innovative process to produce biobased plastic out of cellulose recovered from domestic waste water

The CELLU2PLA project [44] demonstrates an innovative technology that utilises the cellulose contained in municipal wastewater in the production of polyactic acid (PLA). This technology contributes to biobased economy, as it demonstrates cellulose recovery from the effluent of wastewater at a municipal wastewater treatment plant for the production of bio-plastics from cellulose.

2.6.2.1. Market readiness

The CELLU2PLA project aimed to demonstrate an innovative technology in the production of PLA. Cellulose was being investigated as a new resource for the production of lactic acid, the raw material for PLA. The project ended in June 2018.

2.6.2.2. Innovation level

CELLU2PLA is a pilot project that aims to implement a full-scale demonstration (TRL7) of the recovery of cellulose from the effluent of waste water using an innovative treatment process that produces bio plastics from the cellulose

2.6.2.3. Environmental added-value

Multiple results are expected during the CELLU2PLA project, including a 65% use of the cellulose sludge in the production of PLA plus a 70% recovery if the solids of the effluent. Even

[1] *DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*

more both energy use and sludge production will both have approximately 20% reduction. One the other hand, an increase in bio-energy production it is expected to be resulted. Lastly, the overall reduction of the carbon footprint is calculated at 10%.

The effect of the finescreen installation on the wastewater treatment process was monitored during 2017. This is what we found:

- 36% of the unsuspended solids in waste water are filtered out by the finescreens;
- the harvested screening material consists for about 43% out of toilet paper (cellulose);
- the waste collected at the finescreens does not reach the aeration tank, as a consequence the energy consumption for aeration decreases 9%;
- 20% less sewage sludge is formed.

So, less energy is needed for aeration and for dewatering of sludge. On the other hand, the finescreen installation also consumes energy, so overall only 3% less energy is used at the WWTP. Because less sludge is formed, the number of transports decreases and less sludge has to be incinerated. This has a positive effect on the emission of greenhouse gasses. Overall can be concluded that the finescreen installation has a positive effect on the wastewater treatment process.

2.6.2.4. Fulfilment of legal requirements

CELLU2PLA technology incorporates the main directions of the European Strategy for Plastics in a Circular Economy [17].

2.6.2.5. Actors involved and roles

The partnership consists 3 companies each on their field of study:

The Hoogheemraadschap Hollands Noorderkwartier's (HHNK) main task is the purification of wastewater. HHNK is responsible for dikes, protecting people from floods, water, ensuring clean surface and roads, including the management and maintenance.

Attero is getting involved in the treatment of household waste. The first steps include the recovery of raw materials and the production of renewable energy from waste. Attero has developed its own projects based on biobased technologies and products something that make it an important partner to this project. More specifically, Attero focuses intensively on the research and development of the enzymatic degradation of cellulose and PLA production. It also targets an investigation of the marketing of sugar water and PLA.

The Stichting Toegepast Onderzoek Waterbeheer (STOWA) main scope is regional water managing instances in the Netherlands. STOWA offers, develops, acquires, spreads and implements applied knowledge about water management. This knowledge has a background in technical information, science or social and juridical aspects.

2.6.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.7. Nappies

Modern absorbent hygiene products (diapers for babies, adult incontinence and feminine hygiene products) composed primarily of AHP are considered a non-recyclable fraction, which is usually incinerated or disposed of in landfills. At the same time, AHPs are complex products covering three valuable materials (about 30% of their weight): plastics, lint pulp (cellulose fibre) and a superabsorbent polymer (sodium polyacrylate - SAP). These are a huge potential source of secondary raw materials (SRM), opening the way for real recovery.

Initiatives have developed and patented an innovative recycling solution for post-consumer AHP waste, creating secondary raw materials for higher value applications.

2.7.1. Establishing a Multi-purpose Biorefinery for the Recycling of the organic content of AHP waste in a Circular Economy Domain

The EMBRACED project [45] aims to create an environmentally sustainable model of integrated biorefinery which will be based on the valorization technology of cellulosic fraction of absorbent hygiene product (AHP) waste in order to produce biobased building blocks, fertilizers and polymers. This project is ultimately based on circular economy and its purpose of closing the loop of AHP waste and minimizing the use of primary resources.

2.7.1.1. Market readiness

The EMBRACED has developed collection and recycling systems that turn used nappies and similar products into profitable new materials for more sustainable use. It's an ongoing project that started in June 2017 and will end in May 2022 [46]. The market readiness is linked with demonstration activities in industrially relevant environment enabling the valorization technology of cellulosic fraction of absorbent hygiene product (AHP).

2.7.1.2. Innovation level

Throughout this project there will be a demonstration of a process which focuses on converting syngas from AHP waste cellulose into biodegradable polyesters as well as a low-cost process for obtaining 2G fermentable sugars from high purity AHP waste cellulose. Apart from these, there will be also a process for the conversion of sugars obtained by AHP waste cellulose fraction into biobased building blocks and polyesters.

2.7.1.3. Environmental added-value

The environmental value at this particular project is expected to be measured by the completion of the project and after the pilot execution of an optimal process enabling the obtaining of high-quality sugars.

2.7.1.4. Fulfilment of legal requirements

The EMBRACED project will meet all requirements of current legislation for this type of by-products and will incorporate all relevant legislation for polyamides and polyesters.

2.7.1.5. Actors involved and roles

The partners of the project are the following:

Fater is a manufacturer and marketer of leading absorbent hygiene product brands for example, Pampers nappies, Lines sanitary towels etc. The company has fostered a circular economy approach as total commitment wanting to create new competitive advantages, growing at the same time.

Legambiente is an association which cooperates with public institutions in order to foster new and innovative governance as well as economic models. It wants to achieve a more balanced relationship between humans and nature. Its main sectors are biodiversity air and sea quality, sustainable waste management, energy, civil economy, agriculture. Their main activities are about recycling, circular economy with the aim to reduce waste and improve separate collection.

NOVAMOD is an industrial company and leader in the sector of bioplastics, which promotes a bioeconomy model based on efficient use of renewable resources and on the regeneration of local areas. It provides application solutions that ensure efficient use of resources through the whole life cycle. Its model of development aims at building bridges between different sectors and creating new value by collaborating with all the stakeholders in the value chain: from agriculture to research, from industry to waste management, from local institutions to civil society.

MATER-BI, developed by NOVAMONT research, is the innovative family of bioplastics obtained from renewable resources. It is biodegradable and compostable according to the European standard EN 13432 and other international standards. Furthermore, it is a research centre with equipment and facilities such as laboratory scale activities and innovative pilot plants. In the past few years NOVAMONT, has developed technologies for the production of bioplastics and bioproducts.

Contarina is responsible for the waste collection management of fifty municipalities in the Province of Treviso (Italy) through an integrated system involving waste from

production to collection, treatment and recovery, generating a positive impact on the environment as well as on the lives of the citizens.

The Fraunhofer-Gesellschaft (FhG) is Europe's largest application-oriented research organization. Fraunhofer IWKS is a newly established strategic research group, formally part of the Fraunhofer Institute for Silicate Research (ISC) with its distinguished expertise in applied material science. Three major research fields are pursued by IWKS: resource strategies, foresight studies, modelling, lifecycle analysis (LCAs), recycling technologies, and substitution for/of critical materials. Fraunhofer IWKS develops intelligent, cost- and resource efficient products, processes and services. Their research areas cover the whole value chain, from the recovery of valuable substances in fluids, recycling strategies and substitution.

CIRCE Foundation (Centre of Research for Energy Resources and Consumption) is an independent Research Centre to create and develop innovative solutions and scientific/technical knowledge and to transfer them to the business sector in the field of energy. CIRCE's mission is to drive forward improvements in energy efficiency and to spread the use of renewable energy by means of the development of R&D activities and formative actions, thereby contributing to a sustainable development.

Edizioni Ambiente is the leading publisher in Italy about sustainable development and environmental issues. Since its foundation Edizioni Ambiente has been partnering with the most relevant italian stakeholders in the above mentioned fields, in public & private sectors: NGOs, big companies and SMEs, utilities, municipalities, local and national gov., Foundations, associations, consortiums. The compaby proposes a wide range of information services for professionals, managers and public officials.

TerraCycle is the world's leader in the recycling and reuse of non-recyclable postconsumer waste, operating in 21 countries around the world. TerraCycle works with hundreds of major brands and retailers across the globe in the field of recycling used packaging and products (i.e. baby food pouches, biscuit wrappers, coffee packaging, pens, air fresheners, cigarette butts etc.) that would otherwise be destined for landfills. It repurposes that waste into new eco-friendly materials and products.

Procter & Gamble (P&G) is the largest consumer packaged goods company in the world (as measured by market capitalization). It operates in about 70 countries and P&G brands are sold in more than 180 countries. P&G includes brands such as: Always, Ariel, Bounty, Braun, Charmin, Crest (AZ), Dawn, Downy (Lenor), Febreze, Fusion, Gain, Gillette, Head & Shoulders, Mach 3, Olaz, Oral B, Pampers, Pantene, SK II, Tide, Vicks. P&G operates through ten business units that include products like absorbent hygiene products, cosmetics, laundry and cleaning products, oral hygiene products, personal

health care and shaving products. Being a leader in environmental sustainability, it is a partner in the EMBRACED project as it fits its profile and focus on waste and environmental sustainability.

Saponia is leading regional producer of detergents and personal care products with history of over 120 years. Having respect for the principles of sustainable development they aim to get the maximum benefit for the consumer achieving also the minimal environmental impact. Monitoring developments of new eco-friendly materials products and services is Saponia's main focus.

SUEZ Recycling and Recovery the Netherlands is mainly focused on waste management, building new resources from both municipal and commercial waste by intiating sorting installations for household & industrial plastics, wood, construction & demolition waste and other ways to create new products from waste.

Fertinagro Biotech S.L., is a Spanish company, based in Teruel and is also a leader supplier of fertilizers for agriculture in Spain, with production plants in Spain. The company provides training, consulting, sales support and field trials, with the vision to create a common added value, besides the strong commitment to R&D.

Wittenburg BV is a part of the privately owned Wittenburg Group based in The Netherlands. It is a qualified medical compounder designing and manufacturing soft thermoplastic elastomers and speciality engineering plastics compounds to ISO 13485 under the brand name Cawiton®. The company gives technical solutions for highly regulated and risk-averse markets such as medical devices, pharmaceutical packaging, food packaging and drinking water.

2.7.1.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.7.2. LIFE HUBnSPOKE (H&S) – Validation of innovative circular economy model for the valorization of post-consumer AHP waste into high-end products

The project HUBnSPOKE [47] creates a new circular economy model through three main innovations: new logistic system combining distributed waste collection/pre-treatment with centralised valorisation systems; technological and value chain optimisation; new business model validated by key economic actors. Within the project scope one pilot plant with one Spoke (10 ktons/yr) and one Hub able to produce recycled products from AHP waste, with up to 95% of post-consumer pulp, up to 95% of post-consumer superabsorbent polymer (SAP), and recycled plastic granules with at least 70% recycled content.

2.7.2.1. Market readiness

HUBnSPOKE demonstrates an innovative technology in the production of Airlaid materials from AHP cellulose and SAP with higher efficiency. For this purpose, a pilot plant will be installed. Hence, the market readiness is at TRL7.

2.7.2.2. Innovation level

The project aims to create a new circular economy model through three main innovations. First, a new logistic system will be developed, combining distributed waste collection/pre-treatment with centralised valorisation systems and a technological and value chain optimization. Second, the development of a new business model validated by key economic actors is also an innovation. And third, the project's plan also includes a demonstration of a higher efficiency in management of AHP waste, reducing the related environmental impacts and improving its valorisation, when compared to current models. Through the realization of a full pilot – which includes production, testing and certification of 4 final FMCG products (Swiffers, bed pads, printing paper, plastic pellets) – the project will demonstrate the industrial feasibility of its model that substitute, for the first-time, virgin materials with SRMs coming from AHP, following a set of strict tests and validation with production companies and panels of final customers.

2.7.2.3. Environmental added-value

The project's results include the production of recycled products from AHP waste with 95% of post-consumer pulp, 95% of post-consumer superabsorbent polymer and recycled plastic granules with at least 70% recycled content. On the other hand, during the project there will be reduction of 3000 tons CO_2, 200 tons methane, 0.03 tons particular matter and 0.5 tons nitrogen oxides. Also, the total amount of AHP waste ending up in landfills is aimed to be reduced by 10,000 tons in the project's duration.

2.7.2.4. Fulfilment of legal requirements

HUBnSPOKE will be implemented upon the Circular Economy Action Plan [31], one of the main blocks of the European Green Deal [27].

2.7.2.5. Actors involved and roles

The actors involved in the project implementation are namely:

> A joint venture between Procter & Gamble and Angelini group is a manufacturer and marketer of leading absorbent hygiene product (AHP) brands – such as Pampers nappies, Lines sanitary towels and pantyliners, Tampax tampons, Linidor, Dignity and Lines Specialist adult incontinence products, etc. – in Italy. Fater has chosen sustainable innovation and circular economy as a total commitment challenge, which involves the

entire organization and becomes the core of the business model in order to create new competitive advantages and keep growing responsibly.

Contarina is responsible for the waste collection management of fifty municipalities in the Province of Treviso (Italy) through an integrated system involving waste from production to collection, treatment and recovery, generating a positive impact on the environment as well as on the lives of the citizens. The company's daily objectives aim to increase the percentage of separate collection, to reduce the amount of waste produced, to raise the quality of the collected recyclable material, and to improve the service offered, optimising the cost benefit ratio. Contarina SpA is considered an innovator in the development and implementation of solutions for the environment and its protection. In the interest of citizens and municipalities (50) to stimulate the communities to re-examine their relationship with resources and reduce waste production to a minimum.

Alea Ambiente SpA is an entirely public company and deals with waste management according to an integrated system: waste is considered from production to collection, treatment and recovery. Alea Ambiente was born with the desire to release value, promoting the Public Good, protecting the Territory and managing resources in a sustainable way, starting from the prevention of waste production.

Procter & Gamble is the largest consumer packaged goods company in the world (as measured by market capitalization) based in Cincinnati, Ohio (US). It operates in about 70 countries and P&G brands are sold in more than 180 countries, with sales of around $ 65 billion in the fiscal year 2016/2017.

P&G has been a leader in environmental sustainability for decades and continues to make strong progress meeting our 2020 energy, transportation, waste, and water goals ahead of schedule. They are focusing on the areas where they can make the biggest positive difference – Climate, Water and Waste. P&G is a partner in the EMBRACED project as it well fits with the Company focus area on waste.

Favini is worldwide leader in the design and production of textures and finishing solutions for fashion, luxury, design, IT and technical sportswear sectors. Furthermore, it is a leading global producer of graphics specialties, natural fibres-based (cellulose, algae, fruits, nuts, leather etc.), for the packaging of luxury and fashion industries. It also operates in the converting products industry sector that includes activities related to the creation and production of stationery for school, leisure and office, for high-end market.

Cormatex is a textile machinery manufacturer, located in Prato (Italy) and operating on the international markets for more than 35 years. The company has diversified its own

production, becoming a leader in customized solutions for two sectors. The first one includes Woollen spinning: (complete lines for woollen yarn production as well as special technologies for wool deburring and cashmere, alpaca and other fine fiber dehairing). The second one is Nonwoven (complete lines including opening and blending, carding, crosslapping, slitting and winding machines).

2.7.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.8. Carton and paper rejections of MSW

These are waste from wood processing, production and processing of pulp, paper and cardboard. They can be pulp waste (pulp) made from paper and cardboard waste or even fibre waste and fibre sludge from materials.

The main idea of the new strategies is aimed at recovering this waste to be reused by the same paper district that generates the waste of material in the first place and creating a local Circular Economy.

From a highly available biowaste on the market, different biobased products of high interest in the eco-sustainable industry can be obtained: bioethanol, compounds for insulation materials or biodegradable containers among others.

2.8.1. LIFE EPS SURE – Expanded PolyStyrene SUstainable REcycling: From EPS waste to food contact PS final market

LIFE EPS SURE project [48] aimed to offer a technically, environmentally and economically viable solution that allows waste expanded polystyrene (EPS) fish boxes to be collected, stored, pre-treated (compaction, briquetting, washing) and converted into new polystyrene (PS) food contact packaging (for yoghurt and milk), thus closing the loop and managing one of the most difficult packaging flows in Europe. LIFE EPS SURE demonstrated a new environmentally friendly and economically viable idea to manage waste fish boxes. More specifically it aimed to collect about 10 tons of EPS fish boxes from shops across Spain and to produce 40 prototypes of food contact packaging.

2.8.1.1. Market readiness

LIFE EPS SURE packaging developed by MakeGrowLab is made entirely from local agricultural and food industrial wastes: liquid biowaste from beer, wine, juice industry and non-edible vegetable wastes are converted into pulp materials and sheets (TRL 6-7 in 2019).

It has been shown that, with scientific criteria similar to those of PET, the recycling of EPS and PS is technically feasible with the highest levels of demand from the food industry and the European Food Safety Authority (EFSA).

The Life EPS-SURE project opens the way to future new markets for Polystyrene and lays the foundations for achieving food grade authorization and certification by EFSA for polystyrene, a material present in our daily lives.

2.8.1.2. Innovation level

The project introduces a technological approach which is in demonstration level (TRL6-7) and thus contributes to circular economy by closing the loop and managing one of the most difficult packaging flows in Europe.

2.8.1.3. Environmental added-value

The results of the project are including the reduction of landfilling across EU by 70% in Spain and 50% in Greece, Italy and the UK. Furthermore, the project aimed to accomplish a 100% EPS fish recycling rate. Apart from the actual technical plan there will be management in order to inform stakeholders about the environmental impacts of landfilling of EPS fish boxes, representing to them the advantages of the LIFE EPS SURE process.

2.8.1.4. Fulfilment of legal requirements

The project contributes to the implementation of waste legislation including the Waste Framework Directive [30] and the Circular Economy Package [31].

2.8.1.5. Actors involved and roles

The actors involved in the project implementation as well as their role are:

> Anape began in 1979, as the National Association that groups the Spanish Expanded Polystyrene (EPS) industry. In the scientific-technical field participates by: carrying out research, tests and technical reports on the behavior of EPS product; standardization and certification of Expanded Polystyrene products and everything related to their quality; promotion of the environmental management of all the processes involved in the manufacture, use and management of EPS waste, through their adequate recovery; communication about the various recycling options to various stakeholders and participation and collaboration in projects and initiatives at European level.
>
> COEXPAN is the first mover in extrusion with more than 45 years of experience in the industry and specialized in the manufacture of rigid plastic sheets and thermoformed products, to provide solutions for the packaging industry globally.

Total is one of the seven "Supermajor" oil companies in the world. Its businesses cover the entire oil and gas chain, from crude oil and natural gas exploration and production to power generation, transportation, refining, petroleum product marketing, and international crude oil and product trading. Total is also a large scale chemicals manufacturer that aims to find workable solutions to the challenge of finding a way to retain the benefits of plastics while reducing their environmental footprint.

Cicloplast represents Spain before the European organization EPRO (European Association of Plastics Recycling and Recovery Organizations), formed by 19 similar entities that respond to the plastic recycling objectives of the European Packaging Directive. The main objective of Cicloplast is to reduce the amount of waste that goes to landfill and for this it works to promote the prevention and recycling of both material and energy plastics by: collaboration with Public Administrations; technical Activities and Research Projects; environmental Education and Communication Activities

El Corte Inglés, headquartered in Madrid, is the biggest department store group in Europe and ranks third worldwide. El Corte Inglés is Spain's only remaining department store chain.

2.8.1.6. Barriers to replication in other European countries

One of the projects main goals is actually to transfer and replicate the process in other European countries facing similar problems.

2.8.2. LIFE_PHIPP – Paper-hemp insulation pilot production

LIFE_PHIPP [49] is going to demonstrate a new type of building insulation material which is made of recycled paper and hemp fibre promoting its environmental-friendly approach and cost effectiveness. The pilot facility in Latvia will pilot test this kind of technology for producing the soft insulation panels and developing the optimal recipe for the thermal insulation

2.8.2.1. Market readiness

The project started in September of 2018 and will end in September of 2021. In early 2019, the product of the LIFE PHIPP project – a new heat insulation material, which will be made of recycled low class waste paper and hemp fibre, was shown in three international exhibitions – in Latvia, Estonia and Germany.

2.8.2.2. Innovation level

The new product will be easy to install, structurally sound also having insulation properties similar to mineral wool. Apart from these, it will be recyclable achieving one of the main technological goals of the project. At the same time the capability of manufacturing, will be 250 cubic metres per day of paper-hemp building insulation mats, a number that covers 7%

the mineral wool insulation market in Latvia. The manufacturing process and the new product will be presented to at least 50 organisations in Europe, including potential technology entrepreneurs, manufacturers of loose paper or hemp insulation, paper collectors and recyclers, and professional associations of civil engineers and architects.

2.8.2.3. Environmental added-value

This technological approach emerges environmental benefits such as the reduction of gas emissions and hazardous substances plus energy saving.

2.8.2.4. Fulfilment of legal requirements

LIFE_PHIPP technology contributes to the implementation of waste legislation including the Waste Framework Directive [30] and the Circular Economy Package [31].

2.8.2.5. Actors involved and roles

This project is coordinated and ran only by Balticfloc [50] which is the most experienced wastepaper recycling company in Latvia with the broadest array of recycled products. Balticfloc is the only company in Latvia that produces unique paper processing products - cellulose additives to asphalt and absorption materials for collection of environmentally hazardous products.

2.8.2.6. Barriers to replication in other European countries

The innovative technique will be presented to 50 organizations in Europe, including potential technology entrepreneurs, paper collectors and recyclers, manufacturers of loose paper or hemp insulation and associations of civil engineers and architects.

2.8.3. LIFE ECO-PULPLAST – Local circular economy by an innovative approach for recycling paper industry pulper waste into new plastic pallets

The main objective of ECO-PULPLAST project [51] is to achieve zero reduction of paper mill pulp waste that is sent to landfills and incinerators by demonstrating the possibility to recycle pulper waste in the manufacturing of eco-sustainable plastic pallets. A pilot operation tested, including quantitative analysis and testing on physical/mechanical and chemical properties of input materials, while compounds developed and europallets manufactured in the demonstration line.

2.8.3.1. Market readiness

Following the end of the LIFE ECO-PULPLAST project, in August 2018, a detailed 3 year business plan for the industrial development of the project has been drafted. This plan anticipates the creation of 3 complete production lines, with a production capacity of about 1,200,000 pallets/year, corresponding to 60-70,000 t/year of pulper waste.

2.8.3.2. Innovation level

ECO-PULPLAST technology demonstrates a new innovative procedure to recycle pulp waste into new plastic compounds and products, manufacturing new eco-sustainable plastic pallets. In addition, these new plastic eco-pallets could be reused locally by the same paper district which generates the material waste, contributing to a local Circular Economy. At the same time there will be a reduction of the environmental impact stemming from the pulp waste transportation.

2.8.3.3. Environmental added-value

The added value of the technological demonstration related not only to environmental issues but economic ones. A high percentage of pulper waste is expected to be used in the new compounds as well as production efficiency, achieving at the same time a high level of productivity of the prototype. So, it is inevitable a reduction of CO_2 emissions while low energy requirements are included for all the processes.

2.8.3.4. Fulfilment of legal requirements

The project contributes to the implementation of waste legislation including the Waste Framework Directive [30], the Circular Economy Package [31] and the Landfill Directive [32].

2.8.3.5. Actors involved and roles

There are 5 partners who contribute to the development of this technology, each working on its field, including the coordinator.

Selene S.p.A has an extensive background in the production on flexible packaging for industrial consumption. The company converts plastic materials through the phases of exstrusion, printing, sealing. The company main know-how is the development of plastic compounds by using specific combinations of additives to give the required performance (mechanical strength, elasticity, etc.). Its commitment focuses on reusing recovered plastics in its productive process.

LUCENSE SCpA is a consortium-like company, encompassing public authorities, institutions, bank foundations and trade associations as shareholders. Company's main goal is to support local economy, providing also advanced and qualifies services for innovation. It participates in several projects of innovation, experimental development, supporting the technological transfer, centered to environmental sustainability and paper industry.

A main focus of LUCENSE is the testing and validation of green innovative technologies for the recycling of pulper waste and industrial sludge and their reuse in by-products.

SERV.ECO is a consortium of paper mills dealing with environmental issues concerning the paper sector, aiming at the same time at the promotion of research activities, at the production and supply of services, at the design and realization of works and plants, even of demonstrative nature.

Zero Waste Europe helps by offering knowledge and raising awareness in order to re-design the society with another perspective where everything that is being produced can be re-used, composted, repaired or recycled into the system, contributing in a circular economy.

2.8.3.6. Barriers to replication in other European countries

There were not any specific constrains that limited LIFE ECO-PULPLAST's viability plan. On the contrary, they will elaborate a business model in order to provide guidelines to other European paper mills, so that it can be replicated as an approach and help this industry.

2.9. Sewage sludge

Sewage treatment sludge is a nutrient-rich waste product with a high potential for re-use. Since they may contain toxic and pathogenic elements in addition to nitrogen and phosphorus, they are not suitable for food crops. However, they could be used in other value-added uses such as biofuels, added compounds for fertilizers, biopackages and building materials. The following recovery alternatives use sludge from urban wastewater treatment plants.

2.9.1. Bio-coal production via Hydrothermal Carbonization (HTC) of Sewage Sludge.

The TerraNova® Ultra technology [52], which is based on Hydrothermal Carbonization, allows for energy efficient sludge drying to a small amount of solid fuel and integrated Phosphorous recovery – thus treatment and disposal cost are reduced. It is also suitable to stabilize bio-sludge, thus replacing for example biological anaerobic sludge digestion. Dewatered sewage sludge with a dry matter content of 5-30% is conveyed into the input heat exchanger. Then, the preheated sewage sludge is carbonized in an agitated reactor under the addition of catalyst for 3 hours at a temperature level of around 200°C.The resulting coal slurry is cooled down and dewatered to a dry matter content of 65-70%. The extracted water contains valuable nutrients like Phosphorous and Nitrogen that can be recovered as fertilizer. By means of fixation to Calcium Silicate Hydrate (CSH), the Phosphorous is bound and extracted in a filter press. The volume for disposal was reduced to less than a quarter. In addition, in comparison to other sewage sludge technologies, the sludge water, which represents by far the largest component of sewage sludge, is not evaporated but mechanically extracted in a very energy efficient way saving up to 80 % energy compared to drying.

2.9.1.1. Market readiness

The TerraNova® Ultra method has already been proven to work and operate throughout multiple scientific studies during many years of operation on several sewage sludge treatment plants of varying size (TRL9). TerraNova® Ultra is a patented process which won German Innovation award in 2015 and since 2016 is successful in operation.

2.9.1.2. Innovation level

The TerraNova® Ultra technology features a highly efficient heat-recovery, minimizing the heat consumption of the Hydrothermal Carbonization process. The TerraNova® Ultra Hydrothermal Carbonization – based system involves a technology that copies natural coal creation and it speeds it up. Speaking of the procedure, the sewage sludge is being "carbonized" for a two-hour period of time at 200° C and under a pressure of 20 to 35 bar, excluding air. This process transforms it into a fuel much like lignite coal. This fuel can be used to generate energy in lignite coal power plants due to its high energy content lowering at the same time the requirements of energy in cement plants or waste-incineration plants.

2.9.1.3. Environmental added-value

This particular method applies Hydrothermal Carbonization to the sludge and aims to achieve reduction of the sludge amount with smart sludge drying, consuming at the same time approximately 80% less energy than traditional thermal dryers. Even more, the disposal volume is being reduced at 75% and the phosphorous recovery is allowed.

2.9.1.4. Fulfilment of legal requirements

This technology contributes to meet the goals of 2030 climate and energy framework [41] including the EU-wide targets and policy objectives for the period from 2021 to 2030.

2.9.1.5. Actors involved and roles

There is no information available about actors involved in this technology.

2.9.1.6. Barriers to replication in other European countries

There are not any specific constraints that limits TerraNova's viability plan in other countries. Since its method has been applied successfully on several sewage sludge treatment plants and since feedstock availability and legislative framework allows it, this method can be potentially implemented in every EU country.

2.9.2. NutriBiomass4LIFE – Nutrient recycling circular economy model for large cities – water treatment sludge and ashes to biomass to bio-energy

The NutriBiomass4LIFE project [53] aims at demonstration of a sustainable circular economy model for the recycle of nutrient-rich waste for the largest city in Lithuania, Vilnius. The project

will create the first of its kind on the EU level full scale self-sustainable closed loop circular economy (CE) model for large cities' nutrient rich waste - municipal wastewater treatment sludge (MWTS) and biomass ashes – recycling into renewable energy for city's needs via environment friendly biomass plantation phytoremediation filter.

2.9.2.1. Market readiness

The NutriBiomass4LIFE is an ongoing project, started in 2018 and expected to be completed in 2022. Though the pilot case in Vilnius, Lithuania, the project will seek to develop new business models to make it economically viable to grow woody biomass on land that is marginal or unsuitable for agriculture. Until now 1300 ha of existing biomass plantations mobilized for project activities.

2.9.2.2. Innovation level

The process includes the use of both municipal sewage sludge and biomass ash on plants close to the city. The general idea of the project is to find a way to grow woody biomass on land that is marginal or unsuitable for agriculture through new business models making it economically viable. The impact of these circular economy models could be huge contributing to a more resource efficient Europe.

2.9.2.3. Environmental added-value

The project has carefully calculated the expected results. More specifically, 900 ha of woody biomass plantations will be established plus 1800 ha of forests plantation for sustainable forests management. When it comes for sewage sludge and biomass ash a large amount of each will be recycled (27,000 tons sludge and 1,500 tons ash). As for the nutrients, 1,350 tons of nitrogen and 675 tons of phosphorus will be reused in biomass plantations. The environmental impact will be huge because 42,000 tons of CO_2 will be reduced. Furthermore, 39.4 GWh of renewable energy will be produced for Vilnius.

2.9.2.4. Fulfilment of legal requirements

There is no information available about legal requirements for the applicability of this technology.

2.9.2.5. Actors involved and roles

The following organizations and institutions work together as partners for the project purposes on each field of study.

> UAB "Pageldynių plantacija", established in 2010, invests in biomass plantation and focuses on establishment and management activities. It is also one of the leading biomass plantations managers in Lithuania.

UAB "Vilniaus vandenys" is in charge of providing water supply and wastewater collection and services for treatment in Vilnius City.

UAB "Kirtimų katilinė" is supplying heat to municipal district heating network operating biomass boiler in Vilnius.

The Lithuanian Research Centre for Agriculture and Forestry is a research institute and its goal is to conduct R&D in the fields of agronomy, botany, forestry and zoology. Also, the Agreochemical Research Center, the branch Lithuanian Research Centre for Agriculture and Forestry will participate to this project.

Forest and Land Owners Association of Lithuania (LMSA) is an organization which represents the interest of family forest owners. Its mission is about uniting Lithuanian private forest owners and forestry organizations into one association.

Swedish university of agricultural sciences (SLU) is included to the world top ten research and educational institutions in plant and animal sciences. The department of Ecology and Crop Production Ecology will participate to this project and will develop crop production systems focusing on increasing the efficiency of fertilizers.

The Short rotation Forestry group from the Department of Crop Production Ecology will be involved in modelling of biomass growth, LCA, demonstration activities and workshop organization.

2.9.2.6. Barriers to replication in other European countries

Not only were there no any indications for barriers and concerns about replication of the project procedure, but also one of NutriBiomass4LIFE goals is to promote circular economy models and transfer results in other regions inside and outside of Lithuania.

2.9.3. LIFE CoWaCo – LIFE Communal and organic waste conversion

LIFE CoWaCo project [54] combines organic residues and waste materials in order to produce hydrogen and other fuels such as synthetic kerosene, diesel, industrial gases and fertilizers. The vision is to make waste streams usable by converting them into valuable feedstocks in order to shift to a circular economy.

2.9.3.1. Market readiness

LIFE CoWaCo will set up a near-zero emission prototype in Rendsburg, northern Germany, to process biogas and wet residuals (sewage sludge, manure) into sulphur-free, carbon-neutral and high-quality primary products (fuels, lubricants and solvents), and profitable by-products (fertilisers and water). The prototype will be optimised to meet product quality standards. The results of this pilot case will create new market potential for existing bio and sewer-gas plants,

waste disposal and wastewater treatment companies and suppliers of raw input materials. The project is expected to end in December of 2022.

2.9.3.2. Innovation level

This project will utilize processes that already exist in order to convert problematic waste and residual materials into hydrogen and fertilizers. More specifically, the processes include, feedstock preparation, reforming of the feedstocks into synthesis gas, separating of hydrogen and fertilizer production as well as CO-Shift reactor for maximization of hydrogen production.

2.9.3.3. Environmental added-value

All of the actions mentioned above will have positive impacts on the environment. First of all, there will be a conversion of 900 tons of sludge into CO_2- neutral diesel as well as 675,000 cubic metres of biogas. Also, and reduction of 1055 tons of carbon emissions and air pollution is inevitable. Greenhouse gases are also going to be reduced thanks to the utilization of the hydrogen and air quality is going to be improved.

2.9.3.4. Fulfilment of legal requirements

The project will help implement the EU's Roadmap to a Resource Efficient Europe [28] and the Biofuels Directive [38].

2.9.3.5. Actors involved and roles

Infinite Fuels GmbH is the coordinator, specializing in the development of sustainable fuels and fertilisers. It delivers concepts for converting a wide range of input materials from plants to biogenic residuals, organic waste materials and carbon dioxide into sustainable high quality sulphur-free carbon-neutral fuels such as diesel, kerosene and gasoline, as well as concentrated fertiliser.

The Hochschule Für Angewandte Wissenschaft is a university in Munich. It is the largest university of applied sciences in Bavaria and one of the largest in Germany, with fields of studies: natural sciences/ engineering, economics, social affairs and design.

Abfallwirtschaftsgesellschaft Rendsburg-Eckernförde GmbH (AWR), is a company in Hamburg, Germany. The core task of the AWR is public waste management in the Rendsburg-Eckernförde district. AWR was founded in 1992 as a public company together with a private partner company. As a mixed-economy company deals with legal compliance, environmental protection and economic efficiency.

2.9.3.6. Barriers to replication in other European countries

Within the project's planning is to transfer at least one follow-up plant within the EU, something that will contribute to the technology replication in other European countries.

2.9.4. LIFE-DRY4GAS – Waste Water sludge solar DRYing FOR energy recovery through gasification GAS

DRY4GAS project [55] introduces an innovative alternative solution for the reuse of sewage sludge which is generated by wastewater treatment plants. A pilot plant will be used to dry the sludge for use in energy generation, the construction and agriculture. For this purpose, a solar drying system and a thermochemical gasification process will be incorporated. Furthermore, the project will assess the reuse of gasification ashes mixed with sewage sludge for a better quality agricultural additive studying at the same time how to reuse the ashes in the construction industry. Gasification is being used due to the fact that it has low carbon dioxide emissions comparing to incineration.

2.9.4.1. Market readiness

DRY4GAS is an ongoing project launched in 2017 and is going to end by the end of 2022. The purpose of the project is to use the conclusions of a pilot plant to create a new solution for the reuse of sewage sludge.

2.9.4.2. Innovation level

The project proposes an innovative and highly replicable solution for the management and reuse of sewage sludge generated by wastewater treatment plants. It will develop a pilot plant that will incorporate a solar drying system and a thermochemical gasification process to dry the sludge and recover 120 MWh/year of energy by means of an organic Rankine cycle.

2.9.4.3. Environmental added-value

Due to the projects work there are certain results expected. First of all, the use of renewable energy in the drying process will result in reduction of CO_2 emissions (between 880 and 1.111 tons/year). The production of 320 MWh/year and 640 MWh/year of electric and thermal power will lead to approximately 67-83% reduction in wet sludge use in agriculture as well as 20% reduction in the use of chemical fertilizers and water consumption. Generally, the main outcome will be the positive impact on the environment.

2.9.4.4. Fulfilment of legal requirements

The project follows and implements EU policies and legislations. More specifically, with the Sewage Sludge Directive [56] and the Urban Waste Water Directive [57] it promotes the use of sewage sludge in agriculture. The fulfilment of EU 2020 Climate and Energy Package [41] leads to the reduction of CO_2 emissions due to generation of renewable energy in the drying process plus smaller volumes of sludge requiring transportation. Furthermore, following the EU circular Economy Action Plan [31] and the Waste Framework Directive [30] the project will develop a green circular economy model promoting the reuse of sludge for energy recovery,

construction and agriculture advertising also the recovery of the costs of water- related services with the reduction of sludge management costs.

2.9.4.5. Actors involved and roles

The actors involved in the project implementation are:

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (Center for Energy, Environmental and Technological Research, CIEMAT) is a Public Research Agency focused mainly on the fields of energy and the environment and technological fields related to both. With a human team made up of 1,328 people, CIEMAT's mission is to contribute to the sustainable development of Spain and the quality of life of citizens.

The Entidad de Saneamiento y Depuración de aguas residuales (Regional Entity for Sanitation and Wastewater Treatment, ESAMUR) is a Regional Public Company responsible for the Sewerage and Wastewater Treatment and Implantation of the Sewerage Canon Law in Murcia, Spain. Company's main functions include, management and administration of the Sewerage Canon ,exploitation and maintenance of the public facilities of treatment, control and follow-up of the results of the wastewater treatment and sludge, construction, rehabilitation and improvement of facilities, inspection of the sewerage canon applied to industrial spillages to sewerage networks and cooperation with the municipalities in the control of industrial spillages and tasks of dissemination, experimentation and development in wastewater reuse and treatment systems.

Consejo Superior de Investigaciones Científicas, (CSIC) is the largest public institution dedicated to research in Spain and the third largest in Europe. Its main objective is to develop and promote research that will help bring about scientific and technological progress. Its activity is organised around the areas: humanities and social sciences, biology and biomedical science, natural resources, agricultural sciences, physical science and physical technology, materials science and food technology, food science and food technology and chemical science and chemical technology.

2.9.4.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. On the contrary, one of the project goals is to demonstrate an innovative alternative solution for the reuse of sewage sludge that could be used as a guideline of any other European country.

2.9.5. LIFE-ANADRY – Dry anaerobic digestion as an alternative management & treatment solution for sewage sludge

ANADRY project [58] applies Dry Anaerobic Digestion under certain conditions, thermophilic (55°C) and mesophilic (35°C) as a more effective treatment method for the sewage sludge produced in wastewater treatment plants. The plant is installed within the urban wastewater treatment plant of Mula in Spain. This procedure aims to demonstrate that the Dry Anaerobic Digestion has in fact more advantages related to effectiveness and sustainability over other methods for sludge treatment in small to medium-size plants.

This technology examines specific indicators:

- 30% reduction in transport costs and therefore environmental impacts linked to transportation – around 0.225 kg CO_2/km emissions avoided
- Improvement in the quality of sludge produced with an expected reduction of 50-99% in pathogen content
- An 80% reduction of reactor volumes compared to conventional wet digestion (compact digester with higher volumetric organic loading rate), and consequently less consumption of material resources
- Reduction in GHG emissions in sludge stock deposits due to the reduction of quantities of sludge generated and the process applied
- Resource recovery from organic matter as green energy: the biogas produced contributes to the energy self-sufficiency of the WWTP. It is estimated that 376 000 kWh of electricity and 446 760 kWh of thermal energy will be produced by a facility that treats 2 500 m^3/day
- A 70% substitution of inorganic fertilisers thanks to the use of sludge recycled in agriculture and reduction of carbon emissions associated

2.9.5.1. Market readiness

The project completed in February 2019 and its results are available for use. Therefore, its market readiness is not at business level. However, within the project outcomes this technological process has been tested and verified at least at demonstration in a smaller scale.

2.9.5.2. Innovation level

The project tests Dry Anaerobic Digestion (AD) technology under thermophilic (55 °C) and mesophilic (35 °C) conditions as a more effective treatment method for the sewage sludge produced in wastewater treatment plants. The implementation of dry AD of sewage sludge at semi- or pre-industrial scale has not been carried out to date. The project aimed to demonstrate that the abovementioned process offers a vast improvement in terms of effectiveness, cost-effectiveness and sustainability for sludge treatment.

2.9.5.3. Environmental added-value

There are multiple results expected throughout the project's duration that have positive effects on the environment such as approximately a reduction of 0.225 kg CO_2/km emissions due to transportation impacts. Furthermore, the quality of the sludge will be improved with an expected reduction of 50-99% in pathogen content. A reduction in greenhouse gas emissions in sludge stock deposits will also be achieved. One important fact is that the biogas that is produced during the process, contributes to the energy of the wastewater treatment plant. Around 376,000 kWh of electricity and 446,760 kWh of thermal energy will be produced by a facility that treats 2500 m^3/day. There will also be a 70% substitution of inorganic fertilizers due to the use of sludge in agriculture as well as the reduction of carbon emissions associated.

2.9.5.4. Fulfilment of legal requirements

There are no indications that there are any specific constrains for the related technological viability. On the contrary, the project elaborates a business model in order to provide guidelines to other European paper mills, so that it can be replicated as an approach and help this industry.

2.9.5.5. Actors involved and roles

There are five partners involved in this project each on its field of study and association.

Depuración Aguas del Mediterraneo S.L. (DAM) was formed as a service company in Valencia in 1995. The company's main activity is based on service and maintenance of sewage treatment plants and sanitation systems. It has developed water supply systems and purification stations, waste management and recovery of biosolids in agriculture, engineering, installation of domestic waste water works and submarine emissaries, cogeneration and codigestion plants and studies and projects of research, development and innovation (R&D&i), in collaboration with various important institutions.

Ceit-IK4 is a non-profit research center which promotes excellence in applied research by publishing non-confidential results, disseminating scientific and technical knowledge in a variety of venues, and training doctoral students within the framework of industrial research projects.

The Entidad de Saneamiento y Depuración de aguas residuales (Regional Entity for Sanitation and Wastewater Treatment, ESAMUR) is a Regional Public Company responsible for the Sewerage and Wastewater Treatment and Implantation of the Sewerage Canon Law in Murcia, Spain. Company's main functions include, management and administration of the Sewerage Canon ,exploitation and maintenance of the public facilities of treatment, control and follow-up of the results

of the wastewater treatment and sludge, construction, rehabilitation and improvement of facilities, inspection of the sewerage canon applied to industrial spillages to sewerage networks and cooperation with the municipalities in the control of industrial spillages and tasks of dissemination, experimentation and development in wastewater reuse and treatment systems.

INDEREN is a company dedicated to the design and implementation of industrial installations and renewable energy; it is authorized by the Spanish Ministry of Industry as an installer company of gas, heating, plumbing, electrical and fire-fighting systems. Since 2010 INDEREN is specialized in the realization of installations in agribusiness Biogas Plants, having participated in a total of 20 projects in countries such as Spain, Holland, France, Belgium and Costa Rica.

SEMIDE is an initiative of the Euro-Mediterranean Partnership. It provides a strategic tool for exchanging information and knowledge in the water sector between and within the 43 Euro Mediterranean countries of the Union for the Mediterranean. The Union for the Mediterranean is an intergovernmental organization that brings 28 member states of the European Union and 15 Mediterranean partner countries from North Africa, the Middle East and Southeast Europe. Dissemination of information and results on research activities is among its priorities, together with training, data management, documentation and institutional management. SEMIDE works closely with the European Commission and the European Environment Agency in particular for information and data management. It is also a supporting organization for the secretariat of the Union for the Mediterranean.

2.9.5.6. Barriers to replication in other European countries

The purpose of LIFE-ANADRY project was to develop a treatment method for the sewage sludge produced in wastewater treatment plants. There are no indications that this method could not be applied for sewage sludge treatment in every European country.

2.9.6. LIFE COGENERATION PL – Demo installation for electricity/heat COGENERATION with gasification of fuel based on municipal waste and sewage sludge

COGENERATION PL project [59] demonstrates the operation of an innovative technology form managing the energy fraction of municipal waste and sewage sludge. This technology includes the process of gasification, which is a method of producing gas by subjecting certain materials to high temperatures, with a controlled amount of oxygen or air, for the production of electricity and heat.

2.9.6.1. Market readiness

The project ended in 2018 with all activities carried out and all the objectives achieve. For this purpose, a pilot case has been installed and demonstrated a prototype for energy generation from municipal waste and sewage sludge. Hence, the market readiness is at TRL7.

2.9.6.2. Innovation level

The project demonstrates a pilot-scale prototype plant which combines a total of five technological units such as fuel preparation, syngas purification and combustion, gasification, product of energy and exhaust gases purification. This technology tested and validated so that all assumptions for the functionality are certified. Throughout the pilot-scale both the economic feasibility and impact on environmental problem were evaluated.

2.9.6.3. Environmental added-value

This prototype incorporates certain parameters mostly about the power savings derived from its operation.

2.9.6.4. Fulfilment of legal requirements

The project contributes to the implementation of waste legislation including the Waste Framework Directive [21] and the Circular Economy Package [22].

2.9.6.5. Actors involved and roles

Investeko S.A. is a private company specialised in the provision of environmental protection services. Its core activities include outsourcing, environmental consulting, waste management, auditing (Environmental Impact Assessment, IPPC), air protection and design services for environmental projects.

The Taktyk company was established in 2009 as an initiative of people involved in the provision of advisory and consulting services in the field of obtaining funds for the implementation of training, research, development and commercial projects. Technopark employees has a several years of experience in the field of academic entrepreneurship support.

2.9.6.6. Barriers to replication in other European countries

There is no indication that this prototype cannot be replicated and applied in other European countries.

2.9.7. Conversion of diluted mixed urban biowastes into sustainable materials and products in flexible purple photobiorefineries

DEEP PURPLE project [60] is to develop and demonstrate the viability of the concept of a versatile, integrated and flexible multi-platform biorefinery capable of extracting and recovering high added-value compounds from urban waste streams. It will use an innovative approach, implemented by using a novel Multi-Platform Biorefinery Concept (Biomass, Cellulose and Biogas). This will replace current destructive and polluting practices.

2.9.7.1. Market readiness

The DEEP PURPLE is an ongoing project expected to end in April 2023.

2.9.7.2. Innovation level

The DEEP PURPLE concept will optimize the innovative combination of technologies and solutions such as Purple Phototrophic Bacteria (PPB)-based wastewater treatment or biogas bioconversion. These mixed waste streams (wastewater, sewage sludge, OFMSW) are going to be used as feedstock in optimized biogas, biomass and cellulose-platforms to extract and recover high-value compounds like cellulose, polyhydroyalkanoates (PHA) and ectoine for further use in the biobased industries. The potential in greenhouse gas savings is huge. Compounds such as cellulose, sugar-blocks fertilizer and ectoine are being extracted and will also be used as feedstock for biobased products with many potential applications. These actions will lead to bio-cosmetics, fertilizers, bio-packaging, self-repairing construction materials.

2.9.7.3. Environmental added-value

Apart from the technical sector, there are multiple expected results for the environment. It is expected to reduce at least 60% of landfilled Organic Fraction of Municipal Solid Waste and recover 71% of wastewater treatment plant solids. As for the greenhouse emissions, a 20% reduction is expected which is calculated to 420 t CO_2-eq per year.

2.9.7.4. Fulfilment of legal requirements

Following the EU circular Economy Action Plan [31] and the Waste Framework Directive [30] the project will develop a concept of a versatile, integrated and flexible multi-platform biorefinery capable of extracting and recovering high added-value compounds from urban waste streams.

2.9.7.5. Actors involved and roles

There is no information available about actors involved in this technology.

2.9.7.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.10. Olive oil mill waste

The olive tree is known and appreciated for its numerous and indisputable healthy properties, especially in cardiovascular health and improvement of the immune system. Olive extracts (leaf and fruit) are ingredients with high concentrations of oleuropeine, hydroxytyrosol and triterpenes with great cardio-healthy benefits.

Currently, the most advanced extraction and purification technologies are being used to obtain more effective extracts that are close to the real profile of the plant. The proposal uses biobased products obtained in the food, pharmaceutical, nutritional and cosmetic sectors in compliance with the strictest quality standards.

2.10.1. Natac, science to market

The Research and Development unit of Natac [61] exploits olive extracts as they are fully dedicated on developing, researching, manufacturing and marketing ingredients that are being used in food supplements, pet food, feed and functional lipids. Having more than 20 years of experience, the company specializes in the exploitation of organic waste from olive and grapevine-derived extracts. Natac applies vertical integration combining different technologies and processes such as extraction & purification, chemical characterisation and functional & bioactivity characterisation that enable the company to have large varieties of raw material available, specializing in Mediterranean materials and developing ingredients based on a sustainable model. This enables Natac to offer final products with high concentrations of oleuropein, hydroxytyrosol, and triterpenes, as well as a wide variety of innovative, olive-derived formulas with unique applications in the food industry (both nutraceutical, as well as functional foods), and in the pharmaceutical, animal nutrition, and cosmetics sectors.

2.10.1.1. Market readiness

Natac is a company with great experience in developing and manufacturing olive extracts showing that the production of food additives from olive oil industry by-products by extraction is proven.

2.10.1.2. Innovation level

Natac having a broad background in developing functional ingredients based on solid, scientific evidence it works with the most innovative technologies and techniques which varies

depending on the procedure. For the extraction and purification technologies there are several methods applied such as traditional solid-liquid, microwave-guided, ultrasound-guided, pressurized liquid extractions etc. Polyphenol and triterpenes are extracted from olive pomace, olive stones and olive leaves (residues from the olive oil industries). The biorefinery is a multi-substrate and multi-product extraction plant, which can also handle grapes residues.

2.10.1.3. Environmental added-value

Natac has implemented a system of raw materials risk analysis known as HABOID (Hazard Analysis Botanical Identity), which determines each plant's level of risk, according to where it comes from, and guarantees that it meets the strictest quality standards required. Also, the manufacture process is executed according to GMP requirements, under the most relevant food quality standard, holding FSSC 22000 food safety and FAMI-QS animal feed quality and safety certifications.

2.10.1.4. Fulfilment of legal requirements

Natac activities contribute to the implementation of waste legislation including the Waste Framework Directive [30] and the Circular Economy Package [31].

2.10.1.5. Actors involved and roles

Natac is a company headquartered in Spain, yet internationally present with the opening of new markets around the world, while maintaining the strategic location of the manufacturing, R&D and Innovation Unit, and Quality Department that secures European standards. With these standards and its experience, Natac is able to develop and manufacture olive extracts as well as food additives from olive oil by-products.

2.10.1.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

2.11. Sawdust

Sawdust, chips, wood cuttings, particle board and veneer are waste products from the wood processing process and the production of boards and furniture. This material, which is considered as a waste, classified as organic matter, has traditionally been used in biomass processes. At present, various innovative initiatives use wood as a feedstock for the production of bio-chemicals, bio-materials and environmentally sustainable biofuels.

2.11.1. Borregaard wood biorefinery for cellulose and lignosulfonate

Borregaard biorefinery [62] uses wood as a raw material to produce environmentally friendly and sustainable biochemicals, biomaterials and biofuel that can replace oil-based products. Spruce chips is separated into bark and wood. The bark is used as a fuel to produce electricity and heat. The wood is subjected to sulfite pulping (hemicellulose and lignin dissolves) and separation. The solid is cellulose. The black liquor contains lignosulfonate which is recovered form the aqueous phase. A part of the lignosulfonate is converted by chemical modification into vanillin. The remaining liquid is used to produce ethanol by fermentation with yeast. The effluent, still containing C5 sugars, is used to produce biogas. In terms of feedstock, spruce wood is preferred. However, other types of wood can be used as well, including waste wood such as saw dust except from hardwood species that are less suitable.

2.11.1.1. Market readiness

The market readiness is at the higher level (TRL 9+) considering that Borregaard biorefinery is considered the world's most advanced.

2.11.1.2. Innovation level

The innovativeness of Borregaard biorefinery lays on the further processing of the pulp and black liquor derived from sulfite pulping.

2.11.1.3. Environmental added-value

Borregaard is the world's most advanced biorefinery. High raw material utilisation, lower greenhouse gas emissions and products to replace oil-based alternatives provide the sustainable and future-oriented solutions. Borregaard uses renewable and natural raw materials and converts them into valuable products that can replace oil-based alternatives. The products are supplied to major markets such as agriculture and fisheries, medicine and food, construction and environmentally friendly biofuels. The energy production is renewed in both thermal energy and hydroelectric power, and the use of oil is reduced considerably.

2.11.1.4. Fulfilment of legal requirements

The updated EU bioeconomy strategy [63] and circular economy action plan [31] aims at shifting the European economy towards a greater and more sustainable use of renewable resources by 2020. Borregaard's wood-based products are based on renewable, degradable and sustainable raw materials, and can in most instances replace oil-based alternatives. Therefore, Borregaard's products can be a part of the future climate solution [22].

2.11.1.5. Actors involved and roles

Borregaard is organised in three business segments:

BioSolutions develops, produces and sells biopolymers and biovanillin from lignin.

Biopolymers are used as binding and dispersing agents in a wide range of end-market applications, such as construction, industrial binders, agrochemicals and batteries.

Biovanillin is supplied to flavour and fragrance companies, as well as to the food and beverage industry. In addition, BioSolutions carries out trading activities in chemicals which are either linked to lignin-based products or have previously been produced by Borregaard.

BioMaterials develops, produces and sells speciality cellulose mainly for use as a raw material in the production of cellulose ethers, cellulose acetate and other speciality products. BioMaterials also includes cellulose fibrils for industrial applications, which are in the market introduction phase.

Fine Chemicals consists of pharma intermediates and second-generation bioethanol.

2.11.1.6. Barriers to replication in other European countries

Regarding feedstock availability and legislative framework, this biorefinery process can be potentially implemented in every EU country.

2.11.2. LIFE+ GREENJOIST aims at demonstrating the value and feasibility of an eco-innovative recycling process

GREENJOIST [64] demonstrates the value and feasibility of an eco-innovative recycling process able to reuse and valorize wood waste to produce green, high quality and cost-effective joists to be used in different sectors such as manufacturing, transportation, logistics and construction. With a potential to substantially cut the currently landfilled wood waste, amounting to 15 million tons per year, the GREENJOIST project has set out a well-structured plan to promote the shift from using potentially harmful chemicals to natural components in the woodworking industry.

2.11.2.1. Market readiness

The production of high-quality, cost-effective joists from recycled wood waste implemented through the realization of a pilot plant at a pre-industrial, non-commercial scale demonstrating the feasibility and effectiveness of this novel recycling process (TRL7).

2.11.2.2. Innovation level

The innovative and sustainable GREENJOIST solution apart from having high quality, it is way cheaper than the currently used technologies and could substitute virgin wood with eco-friendly recycled product. Regarding to biomass production not all types of wood waste can be used. The ones that can be used are those from wood sawing and/ or pure wood from

urban mining. The rest in the value chain must not be burned as it contains amounts of other substances which can be released into the atmosphere.

2.11.2.3. Environmental added-value

The entire purpose of the project is based on environmental sustainability, the demonstration of the new eco-innovative product with 100% recycled wood joists contributes to beating environmental problems. Furthermore, avoiding the use of virgin wood in the construction of new joists and pallets will save trees while reducing CO_2 emissions for the transportation and processing.

2.11.2.4. Fulfilment of legal requirements

GREENJOIST contributes to the consolidation of sustainable eco-innovative businesses in the EU woodworking industry, contributes also to the achievement of EU 2020 goals for resource efficiency [28], and avoid dangerous impacts on human health and the environment.

2.11.2.5. Actors involved and roles

The GREENJOIST project consortium consists of a group of 5 partners from 4 different EU countries who have combined each their skills and knowledge for an effective and successful result. More specifically, 3 countries (Italy, Spain and Ireland) are involved for the development and validation of the Pilot.

IMAL, is a company based in Italy, specializes in high-tech instruments and equipment. It focuses mainly on the production of engineered wood products and packaging systems. Furthermore, it designed and patented several machines as well as solutions to improve the production process of wood-based panels and other products.

Acimall is the Italian Woodworking Machinery and Tool Manufacturers Association. Its main purpose is the promotion of the Italian industry abroad.

Chimar Hellas is established in Thessaloniki, Greece developing technology and R&D services to the resin and wood-based panel industries. It has also a focus on providing safe and environmentally friendly products and technologies.

J.M. Colomer S.A is dedicated to 3 basic sectors such as machinery and facilities for the production of agglomerate wood panels, of plywood and fine plates of European and exotic woods plus machinery for the treatment of decorative papers for the furniture and decoration industry.

Eirebloc is the first of its kind to produce extruded pallet blocks from recycled wood. It is very committed to a role of environmental leadership in all facets of the business by understanding environmental issues, recognizing that with business activity comes

environmental responsibility, developing innovative and flexible solutions to bring about change, striving to buy and sell environmentally friendly products.

2.11.2.6. Barriers to replication in other European countries

There are not any specific constraints that may limit the technology's viability in other countries. Regarding feedstock availability and legislative framework, this recovery and recycling process can be potentially implemented in every EU country.

3. CONCLUSIONS

After a bibliographic search in different European webs of projects in development, specialized webs of R&D, etc.; a summary of the different technologies found is shown in this Catalogue. All of the solutions proposed are technologies that use the same feedstoocks as those raised in the WaysTUP! project (meat by-product, fish by-product, spend coffee waste, source separated biowaste, used cooked oils, cellulosic rejections of MSWTP, nappies, carton and paper rejection of MSW, sewage sludge, olive oil mill waste and sawdust) to obtain the same kind of biobased products proposed in this Project (bioenergy products, nutrients, additives or food ingredients, proteins from human food or animal feed, bioplastics, intermediate chemicals, etc.).

It is necessary to mention that this is a first version of the deliverable 1.3, related with the task 1.2.: Catalogue of urban biowaste valorization solutions and good practices examples. This document will be completed and expanded when the task 1.2 gets finished at the end of month 42, when it will be submitted the Final version of this deliverable.

All the innovative proposals contained in this document, like the different PILOTS proposed in this project, seek the establishment of new value chains and the generation of new business models in the management of the biowaste.

It has not always been possible to find solutions for the same feedstocks and the same final biobased products, but in these cases they do contemplate one of the two, either based on the treatment of one of the feedstocks contemplated, or they are technologies for obtaining the same type of biobased product.

For each one of the technologies identified, it has been analyzed the following type of information: market readiness, innovation level, environmental added-value, fulfilment of legal requirements, actors involved and roles, barriers to replication in other European countries and applicability of indicators. In all cases it has been tried to find quantitative data that can be weighted by different indicators in the second phase of this task, which will consist on a multicriteria priorisation of different indicators for all the urban biowaste solutions and good practices proposed.

In the final version of the deliverable, more work will be done to obtain more detailed and concrete information on all the proposed technologies in order to obtain a more complete catalogue, as well as it will be included the results of the multicriteria analysis that is going to be developed until the end of the task 1.2 of the Project.

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