A circular economy approach for lifecycles of products and services

Report on pathways for the reuse and recycle food waste

Deliverable 2.2

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Summary

The development of a strategy for the reuse and recycle of food waste is described in this document. The main objective is to describe an efficient and useful method for ensure the principles of circular economy in the agri-food sector. To satisfy the objective, different activities have been performed.

First of all, an inventory of successful approaches has been created. For this purpose, a template has been developed and partners involved in the task have collected different successful cases for the recycling and reuse of food waste. This inventory covers the most important food sectors: meat, beverages, dairy, bakery and vegetables. As well as that, cases involving other sectors and cross to every sector have been included.

The assessment of the successful cases has resulted in the identification of existing trends in reuse and recycling food waste and based on them, a hierarchy of the most profitable approaches has been defined. In addition, this study has shown different methodologies to achieve the reuse and recycle of food waste.

After that, and taking into account this information, the description of the recycle and reuse activities to be implemented in the two DEMOs involving the food sector, vegetable and meat, has been performed.

Finally, a study of the packaging industry in the food sector has been developed. This study covers the current packaging industry, the general aspects about plastics (one of the most problematic materials in the packaging sector) and existing and futures trends for the transition to a more sustainable and circular packaging industry. The analysis of the different stages of the food supply chain have been analysed.

This research has developed opportunities and guidelines to be followed, which can be helpful when planning a reuse and recycling strategy. However, the study of each particular situation will be needed in order to determine which are the most appropriated and efficient actions to be implemented.

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1. Introduction

Nowadays, approximately 1/3 of food produced in the world for human consumption (1.300 million tonnes) is wasted every year along the whole supply chain. In the EU, 88 million tonnes of food, which means 173 kg per person, are wasted every year from primary production until final consumption in homes. The production and management of the food waste generates 170 million tonnes of CO_2 in the EU. The EU has the objective to reduce the total amount of food waste by a 30% in 2025 and 50% in 2030.[1]

Considering these significant figures, to develop a new strategy for food waste reduction in the next years is a crucial aspect for our society.

The aim of this task is to create business opportunities from food waste, aiming at no food waste goes to landfill.

First of all, different successful approaches to food waste reuse and recycling have been gathered so, it is possible to identify which are the best solutions to achieve this purpose. Based on these successful approaches a methodology applicable to the entire food sector is proposed.

A particular emphasis has been dedicated to the packaging sector, present in the food's complete value chain. An assessment of the possibilities for recycling and reuse of the packaging has been performed. This assessment concludes in a proposal of the suitable options for each step of the value chain in order to ensure the sustainability of the packaging.

The description of the activities concerning recycling and reuse to be performed in both demonstrators of CIRC4Life project related to food sector is presented as well in the document.

[1] http://www.europarl.europa.eu/news/es/headlines/society/20170505STO73528/infografia-las-cifras-del-desperdicio-de-alimentos-en-la-union-europea

2. Successful approaches

2.1. Methodology

To define a methodology of the actions to be implemented for the recycling and reuse of food waste, an inventory of existing successful approaches has been developed. These successful approaches, presented in Annex I, are focused in different products which represent the most of the food products consumed[2]. These products are:

- Meat
- Animal feeding
- Beverage
- Dairy
- Processed fruit
- Processed vegetables
- Cereals
- Bakery products

The successful approaches have been studied along the whole supply chain: from primary production to the final selling point. It must be highlighted that not only food waste has been considered, also new innovative business models which reduce the total amount of waste produced are included.

The assessment of the successful cases has resulted in the identification of existing trends in reuse and recycling food waste and based on them, a hierarchy of the most profitable approaches has been defined. The implementation of this hierarchy in the food sector companies will lead to the most satisfactory results from an environmental and circular economy point of view. The actions of this hierarchy are presented in order of preference to be implemented:

1. **To reduce food waste through awareness campaign or developing incentives schemes:**
   These kinds of actions consist on offering incentives and carrying out awareness campaigns in order to get a food waste reduction from the end consumer and other actors involved in the supply chain.

2. **To reduce food waste through its direct reuse:**
   This method consists on providing food waste from selling points, hostelry, overproduction in industry or food products (such as vegetables which do not satisfy standards and aspects specifications) to be sold in supermarkets, directly to people who needed through associations, food banks or specific campaigns or to offer them for sale at a more affordable price. Particularly in restaurants, it will be also useful to use products leftovers in other recipes.

3. **To reduce waste by changing processes or systems**:
   This method is focused on industry and its internal production processes or distribution. Using techniques as hydrolysis or vaporization that could lead to a better management of food waste (that could ease their reduction by other processes) or changing the general view of processes are included in this consideration.

[2] Source Green Foods IEE project.

4. **Use of waste nutrients for food / fats / oils / fertilizers**:
   One interesting approach is to use waste nutrients obtained from food waste to produce different food, pet food, oils, fertilizers or other kind of products that can be developed from food waste nutrients. By this method, nutrients and value properties are maintained in the process. Lots of experiences and successful cases can be found in the market and some of them will be presented later.
5. **Use of food waste for packaging production**:
   Nowadays packaging is a prior issue in terms of sustainability in the food industry, recovery properties and nutrients to develop bioplastic is also an option. By this method, also nutrients and value properties are maintained in the process.

6. **Use of waste for producing sustainable energy:**
   The last kind of actions that can be carry out to benefit from food waste is to produce sustainable energy, preferably to be used in situ. Biogas, biodiesel, or biomass are the most popular energy sources that can be produced from food waste.

It must be remarked that the approach is general enough to be applicable to the whole food value chain and therefore, not every action is meant to be implemented in each step of the value chain. In each case, companies can follow the hierarchy and choose the most suitable actions depending on the subsector and the position in the value chain.

Considering the previous hierarchical structure, under a circular economy umbrella, the proper path of actuation should be trying to reduce food waste and then, when wastes are unavoidable, trying to preserve the food properties in order to be used for subsequent processes. Preserving nutrients and food properties would be always preferable to bio-energy conversion, that should be considered as the final option.

In addition to the presented hierarchy, this study has shown different methodologies to achieve the objective.

Incentives:

Incentives schemes can be helpful to achieve an appropriated waste collection. The incentives offered do not necessarily have to involve direct payment or similar; local events could be a good way to provide them. There are two different methodologies to plan this incentive scheme: the first one is to rewards citizens' efforts and the second one to punish unsustainable attitudes.

An example to establish incentives schemes is to use recycling bins actioned by a loyalty free card of the user. In this card, the information about recycling practices and incentives received will be recorded.

Awareness campaigns:

People behaviour is a really important issue when talking about food waste and its reuse and recycling. Awareness campaigns to provide information to people are essential for this.

Industrial symbiosis:

The assessment of the successful approaches has led to one main conclusion: the importance of companies' involvement in order to achieve the objective of no food waste goes to landfill. The final consumer has a remarkable importance in reducing food waste when it is totally processed,

but before that, lots of steps has been carried out along the supply chain, when lots of waste (not only food) has been produced.

Many times, this waste is not a residue, but it is a by-product that can be useful for another company, or maybe the same, in another different process. For the success of these by-products sharing, administrative and collaboration mechanisms between companies must be developed in order to promote the interchange of this by-products. Public administration has an important role in the promotion and wide spreading of these practices.

New sustainable business models:

Another aspect observed during the collection of successful cases is that new sustainable business models such as in cafes or restaurants which minimize waste and which have the principle of reducing, reusing and recycling waste are useful not only to implement that idea at a local level, but to widespread it and to be an example for people.

Other kind of business as direct or bulk sale are also examples of new sustainable business models.

R&D:

Finally, it is important to mention and to remark the important about Research and Development. This sector provides new techniques, methods and technology to be implemented in the whole supply chain and making possible the sustainable improvement of it.

3. Activities developed in the meat sector

First of all, it should be highlighted that meat sector is already a sector in which circular economy principles are well established and exist common practices in all stages of the value chain. The reason for this is that these practices are economically profitable, and this factor has fostered their spread, jointly with legislation requirements.

As mentioned in the previous chapter, reduction of waste by means of reuse and recycling, should be addressed separately in each stage of the value chain. Therefore, in case of the meat sector we considered the following stages, according to SAT ALIA organization of the value chain in their holding group: 1) Livestock Feed manufacturing 2) Livestock Farm, 3) Slaughterhouse and meat elaboration plant; 4) Selling point 5) Consumers.

3.1. Livestock Feed manufacturing

There are two points of view in livestock feeding manufacturing regarding reuse and recycling: the use of this activity as a tool for reusing residues (properly by-products) of other industries, and the view of the reuse/recycling of the residues generated by this activity.

Livestock feeding has been presented in the previous chapter as a successful approach for food recycling and reusing. This is valid at small farms in which animals are feed with “fresh products” (meaning they are not processed). In this type of farms, it is very common to use vegetables and bakery residues as part of the feeding, as a way of reducing costs.

In industrial feed manufacturing, the use of by-products of other industries is also possible, mainly from bakery industry. Bakery industry sells as by-product biscuit meal, which has become a basic ingredient of livestock feeding composition in the last years. Biscuit meal provides a high content of fats and carbon hydrates, easy digestibility (as it comes from cooked products). Due to those characteristics and what is the most important, providing a constant composition, it becomes a perfect substitute of pure cereal, which is liberated for direct human consumption. In SAT ALIA, the formulation of livestock feed for pigs incorporates a 5-10% of biscuit meal.

SAT ALIA has previously investigated other sources of raw material coming from other industries by-products. Particularly, in their R&D project “Use of biodiesel by-products (glycerine)in pigs feeding” funded by CDTI (Spanish National Technological and Industry Development Center), and developed between 2008 and 2011, it was demonstrated that glycerine coming from biodiesel obtention, with a content in glycerol of 86% can be incorporated in pigs feeding in substitution of corn cereal up to 5% without affecting nutrients digestibility nor the quality of the meat obtained. Besides the incorporation of glycerine in the mixing machinery results in an energy reduction over 18% in the granulation process, due to its lubrication effect. Unfortunately, the bad results of biodiesel sector in Spain over the last years, has resulted in a drastic reduction of this by-product availability, which has trunked SAT ALIA’s plans of incorporating glycerine in their formulations. Nevertheless, in regions with availability of this by-product it results a very profitable option for feeding manufacturers.

When it comes to the residues generated by the feeding manufacturing, the biggest waste in this activity is the rejected final product. This could be due to quality reasons: lack of compactness and similar. This includes rejection before expedition and client’s rejections.

This final product, which is in perfect conditions is reusable, unless specific antibiotics have been incorporated in the formulation.

SAT ALIA, collects these rejected final products in specific containers and remanufacture them as soon as the batch formulation allows it. With this practice, residues of the production line are almost zero.

3.2. Livestock farm

At the farms, most problematic wastes are manure and corpses of dead animals before their sacrifice age.

Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation), establishes the rules for the management of this kind of waste. It is a category 2 residue and requires to be managed by an authorized waste manager.

This Regulation specifies the operating conditions required for rendering animal by-products not intended for human consumption. It lays down the health and surveillance rules applicable to (amongst others) the collection, transport, storage, handling, processing and use or disposal of animal by-products. It incorporates classification of animal by-products: categories (1,2,3) and consequences for further maintenance with it. The Regulation determines the circumstances under which animal by-products are to be disposed of, in order to prevent the spreading of risks for public and animal health.

In addition, that Regulation specifies under which conditions animal by-products may be used for applications in animal feed and for various purposes, such as in cosmetics, medicinal products and technical applications. It also lays down obligations for operators to handle animal by-products within establishments and plants which are subject to official controls.

In Europe, more than 1,35 million tons are produced every year. About 220.000 of these tons are produced in Spain and around 16.000 tons only in the Region of Murcia. The management of this waste involves an annual cost of € 1.160 million and its main management method is incineration.[3]

In a mixed-type swine farm, such as ALIA's farm, which owns about 500 breeding sows and about 1,500 bait pigs per year, it is estimated that 51.5 kg of carcasses/sows every year.

To deal with that issue, ALIA participated in a European project, LIFE METABIORESOR (LIFE08 ENV/ES/0113), from 2010 to 2015. The aim of the project was to build an integrated pilot plant for complete energy recovery of different municipal and livestock waste materials and by-products. The complete process consists on the hydrolyzation of animal corpses, mixture of the result liquid with sludge and production of biogas. The digestate resulting after the biogas extraction is then partially dehydrated and mixed with chipped vegetal debris for the production of pellets to be used in a biomass boiler. The process has a positive energy balance with an output of 14-21% of electric energy (coming from the biogas stage) and a 78-86% of thermal energy (coming from the pellets).

[3] LIFE METABIORESOR (LIFE08 ENV/ES/0113)

Proportions of 4:1 up to 2:1 of wooden debris and digestate (mixed manure and hidrolized slurry after methanization stage) are needed. At the methanization stage, hydrolyzed slurry represented 11% of the mixture, although it could be raised as far as wanted. The constrain regarding this phase is the actual proportion in the generation of both residues: corpses only represent the 0,2% volume of manure generation in a farm.

According to the results of the project, the complete process is capable of reducing 97% of the volume of the residues, although the access to all the wastes intervening in the process is not always easy at a farm stage. This process is ideal to be implemented in a big livestock farm with associated woody crops farm, or in association of livestock farms and municipalities. The economically feasibility threshold for the complete process is 50 KW of installed electric power, which requires an annual manure production of 10.000 tons.

For small farms as ALIA GANADERA the complete process is not economically feasible, although the process of hydrolyzation of corpses is by itself very interesting. Regulation requires livestock farms to hire the collection of corpses to an authorized waste manager, who provides his service weekly. By using the hydrolization system, corpses are collected into a deposit. After load is enough, water and an accelerating substance such alginate (2cc per 10L of water) are added, and an anaerobic digestion takes place during 6 months. Hydrolization tanks need to be installed by pairs, in order to allow the load in one of them while the other is sealed during the digestion process.

Water requirements for the process is 1,25 to 1,5 L per kg of corps, the rest of the water comes by corpses themselves. Additional water should come from rain collection or from a process of phases separation of the manure, in order to be environmentally sustainable. Heat is also required, in order to maintain a constant temperature of 35-40ºC in the deposit, this heat could be provided by a solar installation in order to be auto-sufficient and environmentally sustainable. Mechanical agitation powered by photovoltaic installation is also required.

Once the hydrolyzation process is finished, the result is an organic slurry that could be used in the production of biogas, or as a soil remediation. Regulation (EC) No 1069/2009 though considers this waste as Category 2, so if it is not used in biogas production it must be collected by an authorized waste manager, as the original corpses.

The process by itself does not reduce waste, but it reduces the number of times the waste manager needs to collect corpses residues from once a week to twice a year, this means a reduction of CO2 emissions of 60% each year (taking in consideration a 20t vehicle collecting corpses and making a 50km trip once a week). It also has the advantage of reducing the risk of disease transmission among farms, as the corpses are treated at its farm.

Regarding manure, at this stage, big amount of slurry is produced, which is a major problem of pollution, particularly in areas of intensive farming, as the Region of Murcia, and particularly the municipality of Lorca, where ALIA is established.

Slurry is the most important waste in pig farming. In Spain, 84 million m^3 are generated every year and 500 million m^3 in the EU. The major environmental problems related to this waste are bad odours and GHGs. In addition, the discharge of excess slurry gives rise to serious contamination of the soil and surface and groundwater, causing serious environmental problems in areas of high density. The pollution by nitrates and phosphates also cause eutrophication phenomena.

There are currently different solutions for slurry treatment:

- The most widespread one is the direct application to the soil in crop fields as organic fertilizer. However, according to the Directive 91/676/EEC, only 170 Kg N/Ha in vulnerable areas can be applied. In high density livestock areas, this figure is much higher and not all the slurry generated can be applied directly to the soil.
- The cogeneration plants had a great acceptance in the past, but due to lack of profitability as a result of the reform of the electric sector it is no more a feasible option.
- Nowadays, in most European countries, biodigestion plants are a common solution for slurry treatment. However, in Spain the number of existing represents a testimonial value due to the existing economic and regulatory needs.

To deal with the slurry generation problem, ALIA is involved in RE-LIVE WASTE project, funded by the Interreg MED program. The main objective of this project is to transform livestock waste into organic high-value commercial fertilizers (as Struvite), contributing to smart and sustainable growth and to the creation of new businesses and market opportunities. ALIA will carry out the implementation of innovative technology for separation of liquid and solid fractions of the slurry generated to reduce N and P content, so the pollutant load will be diminished. After that step, this slurry will be treated in a Struvite Precipitation plant. This process will be performed during the RE-LIVE WASTE project implementation, after that, the possibility of continue doing it will be also considered.

As well as that it is important to mention that in the production of livestock food, raw materials obtained for other industries will be used as a source of starch (biscuit meal, obtained from a mix of recycled baked goods) and wheat milling residues will be used as a source of fats. With that, we will include in our process by-products and waste from other industries.

3.3. Slaughterhouse and meat elaborates plant

These two stages of the production chain are studied together due to the fact that residues of both stages are managed in the same way.

An authorised waste manager collects waste at farm slaughterhouse and processed meat plants, performs a thermal process to the waste and derives the resulting products to pet food and cosmetic sector. This meat waste will be collected by COPRESA, the waste manager, and high value products will be obtained from this waste.

Both, slaughterhouse and meat elaborates plant are obliged to manage their wastes as it is stated in Spanish Law 22/2011, from July 28th, about residues and contaminated soils. This national law transposes EU Directive200/98/CE, about residues.

Regulation (EC) No 1069/2009 (see section 3.2.) of the European Parliament and of the Council of 21 October 2009, also regulates this stage, laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation), also establishes the rules for the management of this kind of waste.

3.4. Selling point

At the selling point, the same process is followed as in the previous stages (slaughterhouse and meat elaborates). However, the raw products obtained at the selling point do not have as high quality as those obtained from the slaughterhouse and the meat elaborates plant, so less high value products can be developed with the meat waste produced at this stage. Nevertheless, COPRESA is interested in collecting the meat waste produced in the selling point, although it will obtain less benefit than in the other stages.

3.5. Consumer

The end consumer is not involved in the recycling process described before, so one of the main purposes of this task is to involve him in it. For satisfying this purpose, one of the ideas contemplated by ALIA was to establish an intelligent meat bin to collect meat waste from the final consumer.

First of all, meetings with COPRESA, the waste manager ALIA works with, were hold. In these meetings the company explained how the process works, the different products obtained after the process and also different traceability requirements (proper tracking and identification of deterioration and/or contamination of waste meat brought to recycling. See Table page 14) we should take into account to develop our idea. In selling points, slaughterhouses and distribution, the traceability of the product is guaranteed, but if the end consumers open the product, the traceability will be lost. That is way cooked meat, meat without the original package or meat bought in a butcher shop ("bulk meat"), won't be possible to add to this process.

This is a limitation for the recycling of meat product by the end user. Therefore, if cooked meat or "bulk meat" cannot be added to the recycling process, the collected quantities would be very little.

Even more, in order to guarantee traceability, only meat in the original package could be used for this purpose. This could be understood as promotion of food waste, which is not the objective at all. Moreover, this is not a usual waste at a household, citizens have many options before allowing meat to overpass expire date, such putting it into the freezer.

After that, different personal meetings with Carrefour (one of the most important supermarkets chain in Spain) were hold. The purpose of those meetings was to find a suitable place to locate the intelligent bin. The objective was to locate it in Carrefour Lorca, as this is a place where lots of people go every day. In these meetings, the possibility of collaboration raised, but there were some concerns because of legislation issues, odours and the space that the intelligent bin would occupy. After that meetings, conversation via email and phone calls were maintained, but not a confirmation for the collaboration was made because all the problems mentioned above.

To find another location to establish the intelligent bin was also a key challenge. The intelligent bin has to be refrigerated and, because of that and also because of vandalism, to be located in a covered place is the only feasible option. We also got in contact with ALDI, the other big supermarket which offers ALIA's products in Lorca, but there were difficulties in engaging them. The possibility of establishing the container in ALIA's local store was also considered, however, it was discarded due to the low influx of people. The city council of Lorca was also contacted but there was no possibility of collaboration for that issue.

The study of the existing legislation was made in collaboration with Task 8.4. The main regulations with evidence of risk detected were the next:

Name	Description	Potential project-level risks (description)
Real Decreto-ley 4/2001, de 16 de febrero, sobre el régimen de intervención administrativa aplicable a la valorización energética de harinas de origen animal procedentes de la transformación de despojos y cadáveres de animales. [4]	Aimed at the prevention of spongiform encephalopathies, and addresses the of use of flours of animal origin in the feed of livestock, as well as the separation of risk materials for destruction under appropriate conditions of health and hygiene.	Ensuring the proper tracking and identification of deterioration and/or contamination of waste meat brought to recycling
Orden APM/189/2018, de 20 de febrero, por la que se determina cuando los residuos de producción procedentes de la industria agroalimentaria destinados a alimentación animal, son subproductos con arreglo a la Ley 22/2011, de 28 de julio, de residuos y suelos contaminados.[5]	Linked to Law 22/2011 on waste and contaminated land. Addresses the treatment of waste from the agri-food sector.	Phitosanitary rules can pose very difficult challenges for the reuse of organic matter, e.g. if waste meat deteriorates to become a 'contaminated' product. Costs to the project may be too high.
Real Decreto 640/2006, de 26 de Mayo de 2006, por el que se regulan determinadas condiciones de aplicación de las disposiciones comunitarias en materia de higiene, de la producción y comercialización de los productos alimenticios.[6]	"Partially transposes Directive 2004/41/EC, which establishes food hygiene and the health conditions for the production and placing on the market of certain products of animal origin intended for human consumption, including measures for surveillance of these products. The Directive leaves leeway to Member States to adapt its measures to its local requirements, insofar norms of hygiene are properly observed."	Potential project level risk for the meat demo, whenever meat becomes a 'contaminated' product. European phitosanitary rules are very strict. Costs to the project may be too high. Traceability measures not well developed for food residues.
"Real Decreto 1338/2011, de 3 de octubre, por el que se establecen distintas medidas singulares de aplicación de las disposiciones comunitarias en materia de higiene de la producción y comercialización de los productos alimenticios."[7]	Linked to RD 640/2006	As for RD 640/2006, potential project level risk for the meat demo, whenever meat becomes a 'contaminated' product. European phitosanitary rules are very strict. Costs to the project may be too high. Traceability law not well developed for food residues.

At the Innovation Camp developed in the frame of this project (Krakow, 12th-15th November, 2018), in which experts from different activity sectors and nationalities participated in order to collaborate in the successful development of the project, its opinion was collected. Many experts raised the different problems which has been already pointed out, regarding legislation, avoiding food waste, the small quantity of meat product we could collect or the difficulties of achieving a good location for the intelligent bin.

In Spain, all the municipalities of more than 5.000 inhabitants must have selective collection of organic waste before de 31st of December of 2020 according to the modification of the Ley 22/2011. In Europe, according to the DIRECTIVE (EU) 2018/851 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 this collection must be implemented before the 31st of December of 2023. This means that the possibilities of wide-spreading

[4] https://www.boe.es/buscar/doc.php?id=BOE-A-2001-3319
[5] https://www.boe.es/diario_boe/txt.php?id=BOE-A-2018-2692
[6] https://www.boe.es/buscar/doc.php?id=BOE-A-2006-9300
[7] https://www.boe.es/diario_boe/txt.php?id=BOE-A-2011-16118

the use of the containers just to collect meat waste are limited. Thus, a more feasible and realistic option is to recycling the meat within the organic waste fraction. The most common usage of the organic waste collected in Spain is to obtain compost. For that, no traceability is required and it is possible to avoid all the problems that concerns the collection of meat products. As well as obtaining compost, there are different practices it is possible to implement as obtaining fertilizers or biogas.

Considering this contextualization, we can conclude that the main difficulties and problems regarding the establishment of an intelligent bin container for the recycling of meat products follow as next:

- Legislation: different problems because of sanitary and traceability issues.
- Location: limitations on where to locate it and the need to establish it in a in a covered and monitored area was vital.
- Amount of appropriated meat we would collect: because of the difficulties in the location of the bin, and also the sanitary and traceability restrictions, make it difficult to collect a big amount of meat waste. And, what is more, because of the possibility of collecting small volumes of meat waste, it would be possible that the resources consumed (e.g. energy for fridge refrigeration, transport, etc.) and efforts made will be much higher than the benefits obtained.
- Difficulty for wide-spreading: the selective collection of organic waste will be implemented according to different nationals and Europeans directives. The possibility of adding another container just for meat waste will be really small.

Taking into account all these situations and the suggestions of the experts present in the Innovation Camp, we consider that the best way to develop the recycle of meat products from the consumer is not to collect them separately, but to try a different strategy, which, in addition, may be common for the entire food sector.

So, for the recycling of the meat products by the consumer, an organic waste intelligent bin will be established in the Region of Murcia. This bin will collect not only meat waste, but different kinds of organic waste. It will have a system which will allow people to identify before disposing the organic waste in the bin. The system will provide a receipt with the identification code data of the user.

After that, the user will receive a receipt that he/she will stamp in the bag containing the organic waste, so a traceability of the process will be achieved. By implementing this intelligent structure in the organic waste bin, the user will be able to receive the eco-credits. The intelligent system of the bin will be connected to the ICT platform of CIRC4Life project. The company Recicla y Gana[8] will be the provider of the intelligent bin.

In order to encourage the use of the intelligent bins, awareness campaigns will be developed and compostable garbage will be distributed among the citizens.

After the collection has been developed, next step should be defining the most appropriated valorization of this waste. For this purpose, we have contacted two different H2020 European Projects to find synergies and to propose a collaboration:

[8] https://www.reciclaygana.org/

- H2020 LIVERUR: Living Lab research concept in Rural Areas.[9]

The aim of this project is to expand Living Labs among the rural regions. Living labs are user-centred, open-innovation ecosystems often operating in a territorial context, integrating concurrent research and innovation process within a public-private partnership. The basis for the strategic development of a rural Living Lab is in establishing a sustainable stakeholder partnership; users, policy-makers, companies, researchers enter into agreements on the basis of which they may engage in longer term collaboration.

One of this Living Lab will be developed in the Region of Murcia, in Vega del Segura area. This is a rural and agricultural area in which there are lots of companies which are involved in the agricultural sector and also lots of individual agricultures. Because of that, the possibility of collaboration has arisen, and we will study how to develop a living lab in order to study which are the best possibilities of using the organic waste in the area.

With that, we will close the loop and we will demonstrate how to perform the recycling of the meat waste together with the meat waste. In this living lab, all the stakeholders and relevant actor of the process will be included.

There are also other option and possibilities to find synergies, as H2020 VALUEWASTE: Unlocking new VALUE from urban bioWASTE.[10] We will follow the next steps of this project and will be in contact in the next few months in order to find possible synergies.

4. Activities developed in the vegetables sector

4.1. Introduction

The fruit and vegetable sector are characterised by long supply chains, combined with a need to maintain freshness and quality to point of sale. The vast majority of fruit and vegetable produce in Europe are sold through supermarkets, which commonly means produce is subject to much plastic packaging – creating a resource use and waste challenge, and also high degrees of produce waste both pre- and post-selling.

The aim of the Demonstration is to show how organic and inorganic waste can be reduced and reused in supply chains, on various scales. Whilst the Demonstration in Task 6.4 is on a small scale horticultural farm with short supply chains, most of the principles and practices can be adopted for businesses on other scales and to other markets.

This document describes what recycling and reuse measures to implement in Demonstration Task 6.4, including all issues surrounding waste. This will couple with some of the outputs of the Living Lab to provide actions for Scilly Organics to implement to meet the objective of reducing waste and increasing value.

[9] https://cordis.europa.eu/project/rcn/214746/factsheet/es

[10] https://cordis.europa.eu/project/rcn/218515/factsheet/en

The process of implementing these measures starts in spring/summer 2019 and will be a continuous process of development and refinement through to the Demonstration showcase event in September 2020.

4.2. Organic waste

Organic wastes include all waste material that is organic in origin – i.e. plant based. In the supply chain this would usually include outgraded produce (too large/small/imperfections) and produce from shops either unfit for sale (e.g. rotten), outdated or simply unsold. In some supply chains this organic waste ends up in landfill, which is completely unacceptable socially and environmentally.

All fruit and vegetable wastes can be seen as a resource in two categories:

- Fit for human consumption – for example outgraded or unsold produce. This can be used in processed products, such as jams, juices or processed vegetables (e.g. carrot sticks, potato chips, soups, baby food, etc). It can also be donated to social projects, such as homeless charities, food banks and community associations.
- Unusable produce – for example rotten or badly malformed produce. If not, rotten this could be used for animal feed, or otherwise composted. The composting can be done on farm, if compost is to be used just on that farm; or at a certified composting site conforming to relevant national legislation covering composting standards and movement of compost material, which can then sell compost to farms or gardens.

At Scilly Organics the level of outgraded, outdated or unsold produce is quite low. However, all organic wastes on farm will be composted and returned to the soil to build soil fertility. This also includes other material such as grass cuttings, weeds and hedge cuttings.

This is an extension of existing practice, but improvements in the composting process will lead to an enhanced compost product to use on the farm at Scilly Organics. An increase in soil fertility supports better soil fertility, which impacts positively on crop yields, range and quality, with resultant positive financial impacts.

A dedicated composting area is where organic material is stored. Periodically, at least once a month, this material is mixed in to compost heaps/windrows, to enable heat to build up and the composting process to start properly. This is not a true 'hot composting' system with associated measurements of temperature and CO2 levels. Whilst those systems are efficient and produce a higher quality output, it also requires regular input of material, a certain level of mechanisation, and regular management.

'Cold composting' is more efficient for Scilly Organics given the available resources and input of materials. The compost is turned two or three times, either by hand or using a fore end loader on the tractor. This composting process takes between six months and a year, depending on the time of year.

The finished product – compost, will then be used on the farm for high value crops such as tomatoes and cucumbers in the polytunnels. Generally, this will be used in the spring before the crops are planted out.

An investigation in to the viability of composting green waste from the local community, to support the composting operation on the farm, will be undertaken. See also section below on new products, making use of some outgraded produce.

4.3. New products

Any unsold or unsellable raw food product, assuming it is fit for human consumption, represents an opportunity for processing and increasing value to the company. This is, and has been, a common occurrence in the fruit and vegetable sector for generations, but there is a clear difference between creating new products using waste products, and using primary products.

By using waste products then a resource has truly been created out of waste, and a new circular economy process is started. It is that which Scilly Organics will start to develop as a new business angle.

Linking in with the co-creation process started in Task 7.3 Innovation Camp, and continuing with further co-creation in consumer surveys, new products will be developed. These may include products such as cider, apple juice, jams and vinegar, subject to further co-creation and market testing.

The principle is to reduce the waste of outgraded or unsold produce that can therefore be converted in to a sellable product to consumers. This increases revenue to the farm business and can be sold as an environmentally positive product to consumers.

As the farm currently does not sell processed food products, this addition to farm activities may also offer opportunities in the future to further develop products. In 2019 a trial will be started to make use of any waste produce, and focus on quality and range of processed products. In 2020 these products will be refined, improved and market tested.

4.4. Consumers

Wider actions with different parts of the supply chain gives the opportunity for a ‘multiplier effect’ in terms of reducing environmental and social impacts. In shorter supply chains this is more easily achieved than in longer supply chains, whilst many of the principles are applicable to both. It is also an argument for shorter, more personal and connected supply chains because the human interactions are more prevalent.

Interaction with the consumers of Scilly Organics gives the opportunity to influence food waste in a ‘cradle to grave’ sense. The consumers fall in to two broad categories:

- Public

  Some sales are direct from the farm to members of the public. Actions here would centre around the opportunities to reduce food waste at home, such as better storage and creative cooking ideas. Plenty of existing advice is available and can be disseminated through the farm’s stall, packaging and website. These actions could enable the reduction in food wasted in homes and raise awareness of the impact of wasted food.

- Restaurants

  The majority of Scilly Organics' sales are to a small number of restaurants/cafes. An opportunity exists here to directly talk to the owners/chefs to assess how to reduce food waste. Primarily this would apply to Scilly Organics produce, but the same principles could be applied to all their food products, using a 'measure, assess and action' approach.

  As with the example of Poco Tapas Bar in Bristol (see Annex I), restaurants can do a huge amount to reduce their waste, including:

  - intelligent ordering
  - turning unused food in to by-products
  - record and understand wastage
  - communication between table staff and the kitchen
  - actively look for low/reusable/recyclable packaging on products

Restaurant customers will be engaged in discussion during spring 2019, and encouraged to enter in to a scheme to reduce their food waste and communicate it to their customers. This will be reassessed before spring 2020, and encouragement given to carry on the work to make it a standard part of business practice.

During the Demonstration event in September 2020 other local businesses will be invited to learn about the successes in reduction of food waste, and tips to help them start their own food waste reduction journey. This is the 'multiplier effect', and is strengthened through peer to peer learning, backed up by existing resources from other organisations such as Wrap UK (see Annex I).

4.5. Packaging

A huge consumer waste issue in the fruit and vegetable sector is the use of plastic packaging. This has been highlighted in recent 'Plastic Free' campaigns, a major new environmental movement. Much of this plastic packaging is seen by consumers as both unnecessary and unwanted, which really should focus businesses on (a) why they still use plastics, and (b) what the alternatives are.

In line with many companies in the sector, the major consumer waste from Scilly Organics products is packaging. Some perishable products, such as mixed salad leaves – a major products for the business, is sold in plastic bags for hygiene and freshness. The bags are made from polythene, which is recyclable but currently not accepted in to the waste and recycling system in operation on the Isles of Scilly.

Two approaches will be taken to tackle this issue. Firstly, a scheme will be implemented to recycle plastic bags by having a recycling bin at the vegetable stall of the business. Bags collected here will be sent on for recycling by Scilly Organics privately.

Secondly, experiments in alternative packaging will commence, including biodegradable and compostable bags. This will require research and trials, and be assessed during the course of the project. If successful these will be adopted as the standard bag packaging.

All attempts will be made to minimise any packaging of products at all. Constant reassessment of (a) the need for, and (b) the sustainability of, all packaging will be made on an annual basis.

Transit packaging (i.e. boxes) to restaurants will also be reassessed. Returnable packaging will be considered the priority, but if this is not feasible then recyclable or reusable packaging will be used, in consultation with these customers.

These measures will be started in 2019 and intensified in 2020, leading up to the Demonstration. Consumer feedback will be important to successfully implement solutions, as ultimately sales determine the financial success of the scheme. Measuring the environmental and social impacts of packaging will form part of the consumer interaction (previous section).

4.6. Material inputs and wastes

The largest source of waste comes in the form of packaging materials on inputs to the business, such as machinery, packaging, compost, plants, etc. This packaging can include cardboard, plastics, paper, tapes and other materials. There is also heavier waste from machinery such as tyres, batteries, oil and scrap metal.

The first task will be to improve on farm collection facilities to sort waste, for onward disposal at the local municipal waste and recycling centre. Furthermore, the business will enquire from the Council of the Isles of Scilly, who are the only waste and recycling organisation on the Islands, whether recycling facilities can be improved to accept in other products such as certain types of plastics.

Secondly the business will work with suppliers to encourage them to reduce packaging on their products, and/or use compostable or fully recyclable products. These ‘upstream’ actions would help massively to reduce the amount of waste arriving at the business. One example would be to use paper-backed parcel tape on cardboard boxes, which makes the cardboard easily compostable without having to strip the box of plastic-backed tape first. Another example would be the use of biodegradable bubble wrap or packaging chips instead of polystyrene ones.

The aim is to look at a combination of standard, low-tech solutions as well as more sophisticated and novel solutions. It is expected that a lot of simple solutions will actually result in significant impacts and savings, which would highlight that all businesses can and should act to reduce material wastes.

5. Packaging in the food industry

5.1. Introduction

«Food supply chains often involve large distances and multiple intermediaries. Each stage in the food supply chain, including production, processing, retail and consumption, drives a range of impacts on society and the environment. Packaging can facilitate the safe transit of food and thus plays a central role in the food system. At the same time, packaging practices and the nature of supply chains are under scrutiny as a result of growing concerns over waste and unnecessary resource use» - Institute for European Environmental Policy

Once successful approaches related to the food waste have been collected and a hierarchy of reusing and recycling in the food industry has been defined, a specific aspect should be studied due to its relevance in sustainability: packaging in the food sector.

Food packaging has been demonstrably linked with high levels of waste, terrestrial and marine litter, as well as low rates of re-use or recycling. Paper, cardboard, cans, crystal glasses and plastics do not usually have a sustainable use when they are used for packaging and they are abandoned along the streets, in the oceans or they end in the landfill.

Among all these materials, plastic is the most widely used material for food packaging[11]. An estimate[12] puts plastics from the global food industry as responsible for 15 billion EUR in natural capital impacts annually. By 2020, Europeans are anticipated to consume 900 billion items of packaged food and drink annually.

For this reason, alongside the recently published Plastics Strategy, news that the European Commission will develop a specific legislative proposal on single use plastics is highly welcome. In December 2015, the Commission adopted an EU Action Plan for a circular economy. In this Action Plan, plastics are identified as a key priority and the Commission committed to 'prepare a strategy addressing the challenges posed by plastics throughout the value chain and considering their entire lifecycle'. In 2017, the Commission confirmed they would focus on plastics production and use, and work towards the goal of ensuring that all plastic packaging will be recyclable by 2030. Thanks to this approach, the EU is best placed to lead the transition to the plastics of the future. This strategy lays the foundations to a new plastics economy, where the design and production of plastics and plastic products fully respect reuse, repair and recycling needs, respect of the ecosystems, return to the environment through biodegradability. For this, new and more sustainable materials are to be developed and promoted.

In this context, food industry companies need to reconsider their packaging strategy. When it comes to choosing the appropriated packaging, it is easy to get wrapped up in the aesthetics of the design or the practicality of the size, but the effect that packaging choice may have on the environment should also be considered. At the beginning of the value chain the sustainable packaging possibilities are reduced but as we get closer to the final consumer, plastic use increases and there are more solutions, ideas and possibilities to make a more sustainable packaging.

[11] https://www.ellenmacarthurfoundation.org/assets/downloads/publications/NPEC-Hybrid_English_22-11-17_Digital.pdf

[12] https://www.unenvironment.org/news-and-stories/press-release/plastic-waste-causes-financial-damage-us13-billion-marine-ecosystems

This research will try to provide different solutions and alternatives for a more sustainable packaging in the whole supply chain, and to reduce the use of fossil-based plastics in packaging, and thus its environmental impact, for the different value chain stages. Each stage has its own features and needs when it has to do with packaging. These new options have been discussed and general alternatives to plastic are later on provided, from currently feasible options to recent innovations to be followed, based on successful cases, market trends and scientific articles.

5.2. General aspects about plastics

As mentioned, plastic has a very important role when we talk about packaging and even more when we talk about packaging sustainability. In this section, the main target is general aspects about plastics to have a complete and comprehensive idea about them.

There are two types of plastics: thermoplastics and thermosets. A **thermoplastic is an** "addition polymer" polyolefin made from the combination of propylene monomers. A thermoplastic is a type of plastic that does not change in composition when it is heated. Accordingly, thermoplastics can be moulded repeatedly. Polypropylene (PP), polyethylene terephthalate (PET), high density polyethylene (HDPE), low density polyethylene (LDPE), polyvinyl chloride (PVC), and polystyrene (PS) belong to this category. Thermoplastics constitute about 85% of the overall plastic demand in the EU [1].

In contrast, **thermoset setting plastics** retain their strength and shape even when heated because their molecular chains are chemically bonded into very strong cross-linked networks. These prevent a thermoset object from melting as a thermoplastic would; when thermosets are heated, they crack or become charred. Thermoset plastics are categorized into phenolic resins, amino resins, polyester resins, silicon resins, epoxy resins, and polyurethanes and account for about 15% of the overall plastic demand in the EU [1].

Plastics are classified according to the resin identification codes (RIC), created by the Society of the Plastics Industry (SPI) to develop consistency in plastics manufacturing and recycled plastics reprocessing (Table 1). Codes 1 through 6 currently represent the composition of six specific types of plastic: code 1 refers to polyethylene terephthalate (PET or PETE), code 2 refers to high-density polyethylene (HDPE), code 3 refers to polyvinyl chloride (PVC), code 4 refers to low-density polyethylene (LDPE), code 5 refers to polypropylene (PP), and code 6 refers to polystyrene (PS). They are currently under control by ASTM International organization [2]. It should be clarified that the presence of these codes does not necessarily mean that the product is recyclable.

Table 1: Plastic types and properties [2]

Resin Codes	Description	Properties	Product Applications	Products made with recycled content
	Polyethylene Terephthalate (PET, PETE). PET is clear, tough, and has good gas and moisture barrier properties. This plastic is commonly used in beverage bottles and many injection-moulded consumer product containers. Cleaned, recycled PET flakes and pellets are used for spinning fibre for carpet yarns, producing fibrefill and geo-textiles. Nickname: Polyester.	• Clear and optically smooth surfaces for oriented films and bottles • Excellent barrier to oxygen, water, and carbon dioxide • High impact capability and shatter resistance • Excellent resistance to most solvents • Capability for hot-filling	Plastic bottles for soft drinks, water, juice, sports drinks, beer, mouthwash, catsup and salad dressing. Food jars for peanut butter, jelly, jam and pickles. Oven able film and microwavable food trays. In addition to packaging, PET's major uses are textiles, monofilament, carpet, strapping, films, and engineering mouldings.	Fibre for carpet, fleece jackets, comforter fill, and tote bags. Containers for food, beverages (bottles), and non-food items. Film and sheet. Strapping.
	High Density Polyethylene (HDPE). HDPE is used to make many types of bottles. Unpigmented bottles are translucent, have good barrier properties and stiffness, and are well suited to packaging products with a short shelf life such as milk. Because HDPE has good chemical resistance, it is used for packaging many household and industrial chemicals such as detergents and bleach. Pigmented HDPE bottles have better stress crack resistance than unpigmented HDPE.	• Excellent resistance to most solvents • Higher tensile strength compared to other forms of polyethylene • Relatively stiff material with useful temperature capabilities	Bottles for milk, water, juice, cosmetics, shampoo, dish and laundry detergents, and household cleaners. Bags for groceries and retail purchases. Cereal box liners. Reusable shipping containers. In addition to packaging, HDPE's major uses are in injection moulding applications, extruded pipe and conduit, plastic wood composites, and wire and cable covering.	Bottles for non-food items, such as shampoo, conditioner, liquid laundry detergent, household cleaners, motor oil and antifreeze. Plastic lumber for outdoor decking, fencing and picnic tables. Pipe, floor tiles, buckets, crates, flower pots, garden edging, film and sheet, and recycling bins.
	Polyvinyl Chloride (PVC, Vinyl). In addition to its stable physical properties, PVC has good chemical resistance, weatherability, flow characteristics and stable electrical properties. The diverse slate of vinyl products can be broadly divided into rigid and flexible materials.	• High impact strength, brilliant clarity, excellent processing performance • Resistance to grease, oil and chemicals	Rigid packaging applications include blister packs and clamshells. Flexible packaging uses include bags for bedding and medical, shrink wrap, deli and meet wrap and tamper resistance. In addition to packaging, PVC's major uses are rigid applications such as pipe, siding, window frames, fencing, decking and railing. Flexible applications include medical products such as blood bags and medical tubing, wire and cable insulation, carpet backing, and flooring.	Pipe, decking, fencing, panelling, gutters, carpet backing, floor tiles and mats, resilient flooring, mud flaps, cassette trays, electrical boxes, cables, traffic cones, garden hose, and mobile home skirting. Packaging, film and sheet, and loose-leaf binders.

	Low Density Polyethylene (LDPE). LDPE is used predominately in film applications due to its toughness, flexibility and relative transparency, making it popular for use in applications where heat sealing is necessary. LDPE also is used to manufacture some flexible lids and bottles as well as in wire and cable applications. Includes Linear Low-Density Polyethylene (LLDPE).	• Excellent resistance to acids, bases and vegetable oils • Toughness, flexibility and relative transparency (good combination of properties for packaging applications requiring heat-sealing)	Bags for dry cleaning, newspapers, bread, frozen foods, fresh produce, and household garbage. Shrink wrap and stretch film. Coatings for paper milk cartons and hot and cold beverage cups. Container lids. Toys. Squeezable bottles (e.g., honey and mustard). In addition to packaging, LDPE's major uses are in injection moulding applications, adhesives and sealants, and wire and cable coverings.	Shipping envelopes, garbage can liners, floor tile, panelling, furniture, film and sheet, compost bins, trash cans, landscape timber, and outdoor lumber.
	Polypropylene (PP). PP has good chemical resistance, is strong, and has a high melting point making it good for hot-fill liquids. This resin is found in flexible and rigid packaging, fibres, and large moulded parts for automotive and consumer products.	• Excellent optical clarity in biaxially oriented films and stretch blow moulded containers • Low moisture vapor transmission • Inertness toward acids, alkalis and most solvents	Containers for yogurt, margarine, takeout meals, and deli foods. Medicine bottles. Bottle caps and closures. Bottles for catsup and syrup. In addition to packaging, PP's major uses are in fibres, appliances and consumer products, including durable applications such as automotive and carpeting.	Automobile applications, such as battery cases, signal lights, battery cables, brooms and brushes, ice scrapers, oil funnels, and bicycle racks. Garden rakes, storage bins, shipping pallets, sheeting, trays.
	Polystyrene (PS). PS is a versatile plastic that can be rigid or foamed. General purpose polystyrene is clear, hard and brittle. It has a relatively low melting point. Typical applications include protective packaging, foodservice packaging, bottles, and food containers. PS is often combined with rubber to make high impact polystyrene (HIPS) which is used for packaging and durable applications requiring toughness, but not clarity.	• Excellent moisture barrier for short shelf life products • Excellent optical clarity in general purpose form • Significant stiffness in both foamed and rigid forms. • Low density and high stiffness in foamed applications • Low thermal conductivity and excellent insulation properties in foamed form	Food service items, such as cups, plates, bowls, cutlery, hinged takeout containers (clamshells), meat and poultry trays, and rigid food containers (e.g., yogurt). These items may be made with foamed or non-foamed PS. Protective foam packaging for furniture, electronics and other delicate items. Packing peanuts, known as "loose fill." Compact disc cases and aspirin bottles. In addition to packaging, PS's major uses are in agricultural trays, electronic housings, cable spools, building insulation, video cassette cartridges, coat hangers, and medical products and toys.	Thermal insulation, thermometers, light switch plates, vents, desk trays, rulers, and license plate frames. Cameras or video cassette casings. Foamed foodservice applications, such as egg shell cartons. Plastic mouldings (i.e., wood replacement products). Expandable polystyrene (EPS) foam protective packaging.
	Other. Use of this code indicates that a package is made with a resin other than the six listed above, or is made of more than one resin and used in a multi-layer combination.	Dependent on resin or combination of resins	Three- and five-gallon reusable water bottles, some citrus juice and catsup bottles. Oven-baking bags, barrier layers, and custom packaging.	Bottles and plastic lumber applications.

As seen in Table 1, practically all plastic types are involved in the packaging of some kind of food.

5.2. 1. Recyclability of plastics

Except for thermosets, almost all plastic types can be recycled. In each recycling process, these undergo modifications in their structure or become contaminated and cannot be recycled repeatedly. Therefore, each time plastic is recycled, additional virgin material is added to help upgrade its quality, and thus, this recyclability is not complete.

In practice the plastics recycling market in Europe is dominated by five main categories, which account for around 75% of converters' demand [3]:

- Polyethylene (PE, including low density-LDPE, linear low density-LLDPE and high density – HDPE);
- Polypropylene (PP);
- Polystyrene (solid-PS and expandable – EPS)
- Polyvinil chloride (PVC); and
- Polyethylene terephthalate (PET)

Moreover, for certain polymers, the corresponding recycling paths have been established and thus, packaging which can be assigned to one of these streams using current sorting technology will be considered recyclable[13]:

- PET-bottles
- PE-LD (including small films and PE-HD/PP films)
- PE-HD/PP (including Crates & Pallets)
- Pots, Tubs & Trays (polyolefins)
- PVC from the building industry (no packaging)
- Technical Plastics (electrical and electronic devices; no packaging)

An important aspect about plastic recyclability is that it is also hindered by the mixing of different kinds of plastics in a given product. For instance, a small amount of PVC contaminant present in a PET stream will degrade the recycled PET resin and vice versa. Therefore, the cleaner and the fewer different types of plastic, the less mechanical treatment is required and the higher the quality of the recycled plastic products are. [3]. What is more, most of the times it is not possible to recycle multi-layered plastic because of the different properties of each layer.

The colour of the package is also very important. Dyed and pigmented plastics, for example, can be troubling for materials recovery facilities as they have a much lower market value. This is why clear plastics are always preferred in the recycled materials market, and have the highest material value. This is because transparent plastic can typically be dyed with greater flexibility. The next best colour is white, as its only limit is that it cannot become transparent but can be made into any other colour. However, the coloured plastics (especially opaque varieties) are often limited to become darker shades of the original dye, or black. For this reason, some recycling facilities consider certain pigmented plastics as contaminants to the recycler stream,

[13] According to Plastics Recyclers Europe. http://www.recyclass.eu/en/information/recycling/ (Last access 29/06/2018).

and subsequently dispose of them instead of recycle them. This issue is extenuated with the low cost of crude oil, making even harder for recyclers to compete with the price of virgin polymers[14].

	YES Full compatibility — Materials that passed the testing protocols with no negative impact OR materials that have not been tested (yet), but are known to be acceptable in PET recycling	CONDITIONAL Limited compatibility — Materials that passed the testing protocols if certain conditions are met OR materials that have not been tested (yet), but pose a low risk of interfering with PET recycling	NO Low compatibility — Materials that failed the testing protocols OR materials that have not been tested (yet), but pose a high risk of interfering with PET recycling
Container	PET		PLA; PVC; PS; PETG
Colours	transparent; light colours	transparent; dark colours	opaque; metallic
Barrier	SiOx coating; carbon plasma-coating; PA multilayer with no tie layers; PTN alloy	EVOH multilayer with <3 wt%; EVOH and no tie layers; PA multilayer with tie layers; monolayer PA blend; PGA multilayer	EVOH multilayer with >3 wt% EVOH or tie layers
Additives		UV stablilisers; AA blockers; optical brighteners; oxygen scavengers	bio-/oxo-/photodegradable additives; nanocomposites
Closure Systems	PE; PP (all with density <1 g/cm³)		materials with density >1 g/cm³ (e.g. highly filled PE, metals); non-detaching or welded closures
Liners, seals and Valves	PE; PE + EVA; PP; foamed PET (all with density <1 g/cm³)	silicone with density < 0.95g/cm³	materials with density >1 g/cm³ (e.g. PVC, silicone, metals)
Labels	PE; PP; OPP; EPS; foamed PET or PETG (all with density <1 g/cm³)	lightly metallised labels (density <1 g/cm³); paper	materials with density >1 g/cm³ (e.g. PVC; PS; PET; PETG; PLA); metallised materials; non-detaching or welded labels
Sleeves	Partial bottle coverage in PE; PP; OPP; EPS; foamed PET or PETG (all with density <1 g/cm³)	sleeves translucent for IR detection in PE; PP; OPP; EPS; foamed PET or PETG (all with density < 1 g/cm³)	materials with density >1 g/cm³ (e.g. PVC, PS; PET; PETG); metallised materials; heavily inked sleeves; full body sleeves
Tamper Evidence Wrap	PE; PP; OPP; EPS; foamed PET or PETG (all with density <1 g/cm³)		materials with density >1 g/cm³; (e.g metal; PVC; PS; PET;PETG); metallised materials
Adhesives	water or alkali soluble in 60-80 °C	hot-melts; pressure-sensitive labels	
Inks	non toxic; follow EUPIA Guidelines		inks that bleed; toxic or hazardous inks
Direct Printing	laser marked	production or expiry date	any other direct printing
Other Components	base cup, handles or other components which are separated by grinding & float / sink (all with density <1 g/cm³); PET		materials with density >1 g/cm³ (e.g. metal, RFID tags); non-detaching or welded components

Figure 1. Compatibility of PET bottles with other types of plastics. Source: http://www.recyclass.eu/.

Recycled plastic can be used in packaging with certain limitations. The most common practice is the use of own plastic scrap as a raw material. This ensures the quality and specifications of the resin. The main concern of plastic converters when using recycled material is the issue of not knowing the exact origin and composition, that is, its traceability. Indeed, the major challenge is the quality of the recycled material obtained, as usually recycled material includes cross-contamination that hinders its use in certain applications. For instance, thin films due to their thickness will have less probability to contain recycled materials, although the use of recycled plastics in films is increasing too, especially in bags. In turn, it is more likely that PET bottles contain recycled content. The average recycled content of PET bottles is 11,7%[15].

According to data of World Economic Forum, 2016, just 14% of plastic used for packaging was destined to a recycling process and only 2% was effectively recycled, 8% was recycled into lower-value applications and 4% was lost in process.

[14] Source: http://www.sustainablebrands.com/news_and_views/waste_not/tom_szaky/many_challenges_plastic_recycling.

[15] According to European Plastics Converters. https://www.plasticsconverters.eu/project-1. Last access: 29/06/2018.

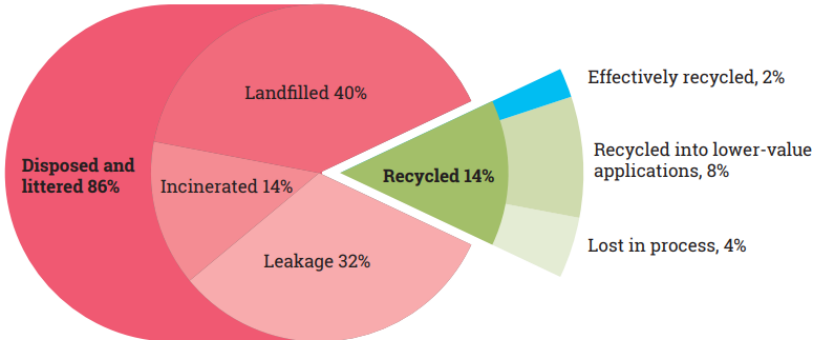


Figure 2. Plastic flows after use[16]

Data from the European Commission shows that 39,9% of the EU plastic demand in 2015 was destined to packaging, and 59% of EU plastic waste generation in 2015 was because of packaging too.

Because of all these difficulties in the recycling process of oil-based plastics, the large amount of single-used plastics which are used for food packaging, as well as the difficulties in the collection process, to rethink plastic economy has become a prior objective for the European Commission.

5.2.2 Bio-based and biodegradable plastics

Bio-based polymers or bioplastics are a promising alternative for oil-based plastics with similar properties and lower environmental footprint. The main drawback of these polymers is found on its cost. Depending on the type of biopolymer, the cost may be 1,5 to 4 times higher than oil-based plastics. Yet according to European Bioplastics[17], "*with rising demand and more efficient production processes, increasing volumes of bioplastics on the market and oil prices expected to rise again, the costs for bioplastics will soon be comparable with those for conventional plastic prices*". Another issue is the current availability of biopolymers in the market.

[16] https://wedocs.unep.org/bitstream/handle/20.500.11822/25496/singleUsePlastic_sustainability.pdf?isAllowed=y&sequence=1
[17] https://www.european-bioplastics.org/faq-items/how-are-costs-for-bioplastics-developing/

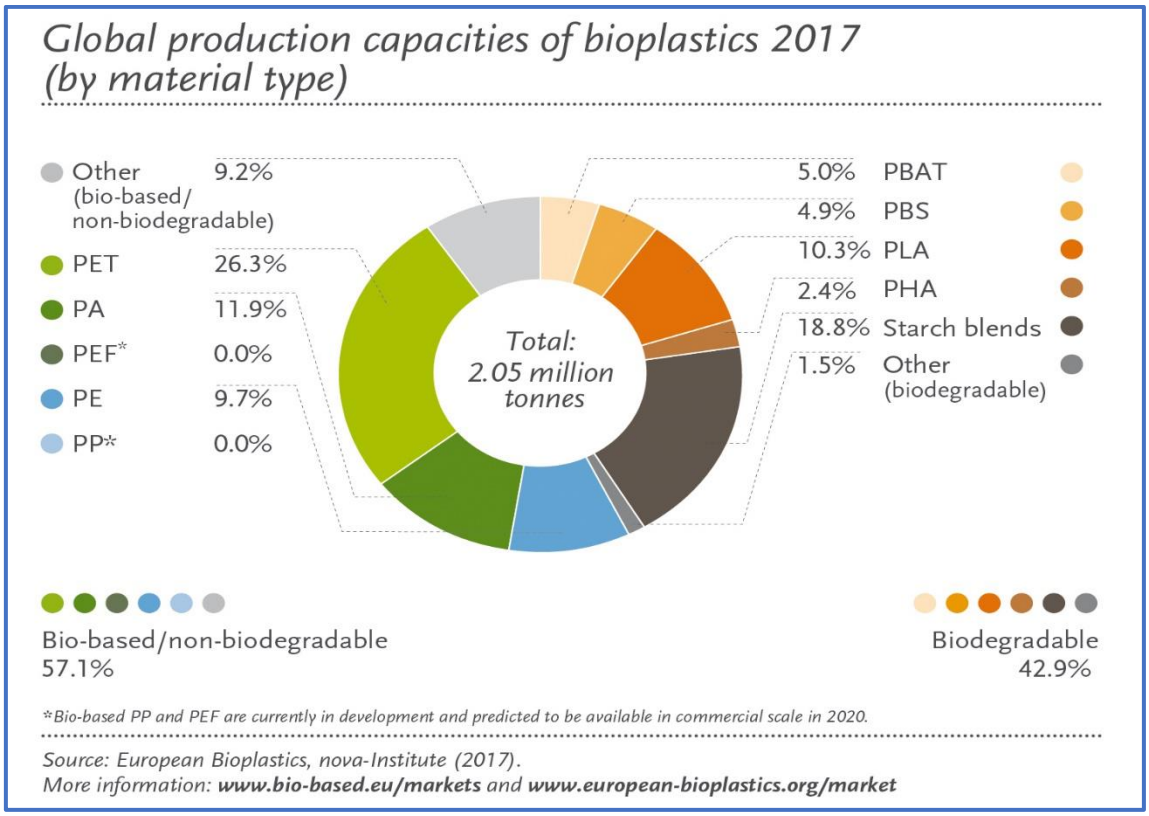


Figure 3: European Bioplastics. Source: www.bio-based.eu/markets

There are also plastics that are both bio-based and biodegradable, such as PLA (Polylactic Acid) and PHA (Polyhdroxyalkanoates) or PBS (Polybutilene Succinate) and thus have an even smaller environmental footprint[18]. Biodegradable plastic decomposes naturally in the environment for a significantly shorter period of time (depending on the type, it may decompose in months or some years). This is achieved thanks to microorganisms which metabolize and break down the structure of the biodegradable plastic. That said, a biodegradable plastic will not decompose if it is not disposed of properly. Littering a biodegradable plastic is thus a non-adequate practice, it requires to put in place a sorting and waste management system for their proper treatment

[18] Plastics that are based on fossil resources and are biodegradable are for instance PBAT or PCL.

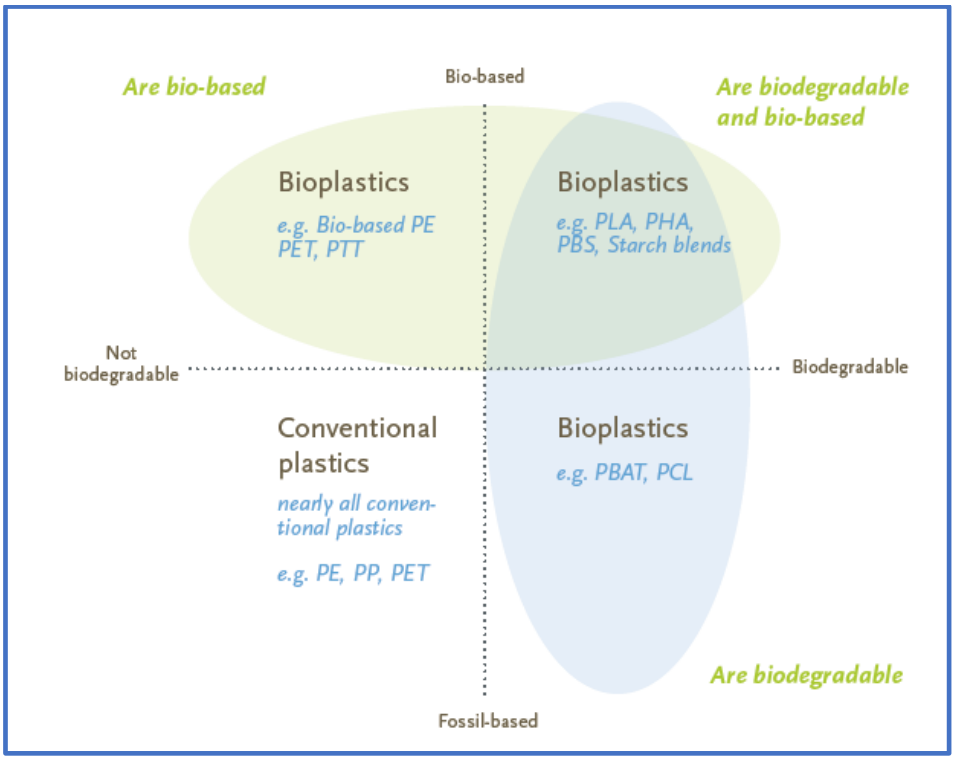


Figure 4: Bio-based vs Biodegradable plastics. Source: EUPBP [4]

There are also certain commercial additives that can be incorporated into oil-based plastics to turn the original plastic into biodegradable. An example is Poly-Bi®[19], which, according to the company, if added on a "2% by weight, this quantity does not change the properties of the polymer, and in this way, you get a polymeric material with the same properties of the starting polymer and uniformly biodegradable". EcoPure® is another additive that can be used to convert conventional packaging into biodegradable.

5.3. Packaging in the different value chain stages

5.3.1. Introduction

To understand how is the packaging scenario in the whole supply chain of food industry, we must identify the different stages involved as sustainable problems and solution may differ at each stage. We have classified four different areas to study: agriculture and livestock, food processing, supermarket and restaurants and transport, which will be present in each step of the supply chain. For each step, the hierarchy of reduce, reuse and recycle will be considered to use the most sustainable packaging whenever it is possible.

5.3.2. Agriculture and livestock

When talking about agriculture two phases must be differentiated: planting and harvesting.

The first phase focuses on fertilizer and seeds packaging. Here the main type of package are sacks. They must have an ergonomic size and weight as a fundamental aspect, but once these requirements are met, they must be shaped and dimensioned in order to reach the minimum

[19] https://poly-bi.com/en/

necessary package area. Nevertheless, when it has to do with harvesting, there are different options depending on what the farmer is going to do with the crop. It is possible to sell the crop directly to the consumer or to provide it to a large retailer.

When providing a large retailer, methodology is pretty much the same as for fertilizers and seeds (shape, dimension, etc), but fruits and vegetables need different transport conditions from fertilizer or seeds which ensures their preservation and security for an often-long route to keep product quality to the retailer. If plastic containers and boxes are used for this, it is important that they can be reused lots of times.

When selling the product directly to the consumer (e.g. street markets), then, distance between farm and final consumer is regularly much smaller. Here, farmer can select different alternatives of packaging. As travel route from farm to street markets is frequently short, transport conditions do not need to be as strict as when providing to a large retailer. In addition, as grower, transporter and seller are the same person, packaging used to transport (and sell) the product might be reusable.

Once in the selling point, the most interesting packaging form is simply no package but bulk selling, choosing cardboard or paper boxes to show the fruit/vegetable and paper bags if the consumer ask for them.

On the other side, packaging in the field of livestock is mainly present in animal feeding. Plastic packaging must be replaced by other materials such as bioplastics or kraft paper.

Figure 5 Kraft paper sacks for livestock feeding (source https://biinform.com/Reports/3700573403_lien-hiep-packgage-production---trading-co-ltd---company-profile-3.html)

Other activity that could be considered is animal watering, but nowadays there are many mechanisms to fill troughs or to water the animals with no need of packaging and allow efficient use of water, like nipple waterers, which enable water volume regulation and just need a big water deposit that spread water to every nipple.

Figure 6. Nipple waterers (source www.the-chicken-chick.com)

5.3.3. Processing

In this stage is where food and beverages are processed and packaged for their distribution to final consumers and where lots of single-used plastics are applied.

It is important to know and to be concerned about the need to reduce packaging whenever is possible and feasible. Without limiting the foregoing, when packaging is necessary it must tend to eliminate the use of fossil-based plastics. Nowadays, there are different alternatives such as bioplastics, paper or cardboard. In addition, packaging size should be conditioned as much as feasible by the amount of product it contains, not only by aesthetical or perception purposes.

For meat, seafood, cold meat and cheese, plastic trays can be replaced by cellulose, bioplastic (e.g. PLA and PHA), or cardboard trays.

Figure 7. Cellulose based trays and films (source www.the-complete-package.com)

When talking about barriers and films, alternatives are more limited. Oil-based plastics have certain properties of elasticity and water vapor impermeability that many bioplastics do not. However, solutions have arisen in the last few years and the limitations of sustainable package use will be reduced in the future. Some solutions may be based on the use of cellulose-based films or coating.

Figure 8. Cellulose based trays and films (source www.the-complete-package.com)

For beverages (water, milk, drinks, etc.), feasible solutions are currently quite limited, although in the last few years different solutions have also arisen and the use of bioplastic and sustainable materials are starting to be considered as a possible solution. Glass and aluminium bottles are nowadays the most extended solutions together with returnable/refillable bottles.

Currently alternatives might be limited but, in the not-too-distant future, they will be feasible. Leading brands are concerned about plastic issue and work to find alternatives to this material. The Ellen MacArthur Foundation announced at the World Economic Forum on January 22nd 2018 a list of 11 big brands, such as PepsiCo and Coca-Cola, working towards using 100 per cent reusable, recyclable or compostable packaging by 2025. Also, the brewery company Carlsberg is working on an ambitious project: a bottle made entirely from biodegradable and sustainably sourced wood fibres. With all of these companies working hardly to eliminate plastic in their packaging new techniques, technologies and materials will emerge.

Figure 9. Coca-Cola Plantbottle (source https://www.coca-colacompany.com/plantbottle-technology*)*

When it comes to beverages with special requirements and needs (for example milk, requiring pasteurization), sustainable packaging solutions are more complex. Bulk selling could become an alternative, being the customer who brings the recipient to the selling point, or with a system of returnable bottles put in place.

5.3.4. Supermarkets and restaurants

Supermarkets and restaurants are the last step before reaching the final consumer.

Connecting with society needs, demands and values is a key aspect for a company since it is the best way to create the most important asset a company can have: customer loyalty. Many marketing researches ensure that building emotional links with customer values and ideas has a strong impact in companies as it does participate in beneficial projects socially well seen, the so called «corporate social responsibility». Therefore, what does all this have to do with packaging? Here is where the visual part of the whole value chain is. It is what the consumer sees, perceives and accepts. In the one hand, this can be a disadvantage, because customers could prefer to buy in a safe and convenient way, and plastic packaging provides this feeling. On the other hand, nowadays more and more people are trying to run a plastic-free lifestyle or, at least, they would like to have more sustainable habits. Connecting with this increasing feeling and meeting these people demands could have benefits for the company, the consumer and, especially, the planet.

Recycling, Reusing, Reducing and Rethinking packaging is an important issue for supermarkets nowadays and will be more important in the future. How to do it? The first step is the most important, simple and logical one: eliminate packaging when it is possible. Bulk selling is the alternative. It might not seem innovative, and it is not, which is its main advantage: it was already done before, for decades, and it is feasible again nowadays. Fruits, vegetables, cereals, nuts, legumes, coffee, tea, salt, sugar, cocoa, seasonings and seeds make up a large list of bulk saleable products.

Figure 10. Bulk selling (source www.unplash.com)

When it comes to meat, cold meat and seafood, preservation conditions are stricter. Bulk selling is possible through butcheries and fish shops. Another alternative is to use bioplastics, paper and cardboard. The problem is that supermarkets receive products already packaged from providers, so it is their duty to choose a supplier that packages his product with materials different from fossil-based plastic such as bioplastic (e.g. PLA), cardboard, etc.

Figure 11. Butchery and fish stall (source: www.pixabay.com)

When it comes to restaurants, there are many ways of carrying on with a sustainable packaging, from pantry to food service. As in any of the other value chain stages, the golden rule is to avoid packaging when it is possible and feasible. Once it is done, there are plenty packaging solutions that allow packaging reduction and to use it with sustainability. In the case of drinks and soft drinks, many restaurants use refilling or, in the case of water, have their own glass bottles which wash and refill.

Nonetheless, this will not be considered as an option for some types of restaurants In these cases, the best solution is to order, if the brand provides it, the glass bottle version over the plastic one. However, as mentioned above, more and more companies are trying to provide bioplastic bottles and cans in a not-to-far future, so this will make it easier. Then, something that might seem to have a tiny environmental impact but actually nothing could be more untrue. An example is straws. Tons plastic straws end up in the ocean because of their light weight. There is a wide range of plastic-free straws: paper, metal, rye, steel, bamboo, etc.

Another important issue for restaurant is take away food. Plastic bags have to be replaced with paper, cloth or cotton bags. Cups can be made of cardboard and lids of PLA. Another interesting option is to have a returnable packaging chain. The restaurant can choose to have a refill alternative (restaurant fills customer's own container) or a returnable option,

where the consumer pays an extra price for the container only the first time the client orders take away food. Thereafter, this container can be reused. The restaurant takes customer's container and provides the food already packaged in a new container without any extra fee for it. Materials can go from PLA, CPLA (heatable) to glass.

5.3.5. Transport

Transport is a transversal activity amongst the whole value chain, from the farm that produces the food to the customer who buys it.

We can differentiate between three types of packaging depending on the amount of product packaged: Primary packaging is product's packaging itself. The main purpose of the secondary packaging is for branding display and logistical purposes, as well as protecting and collating individual units during storage. Tertiary packaging facilitates the protection, handling and transportation of a series of sales units or secondary packaging in order to group everything into unit loads during transit. This type of packaging is rarely seen by the consumer.

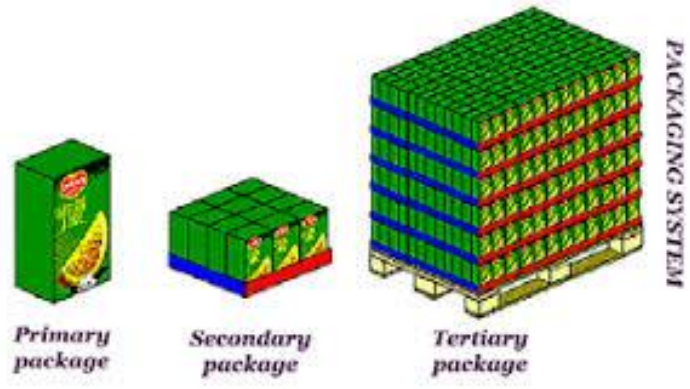


Figure 12. Packaging system (source European Organization for Packaging and the Environment.

Primary package has been treated throughout this document. Secondary package commonly is made out of cardboard. Tertiary package should use cardboard or wooden boxes for small quantities and wooden pallets for bigger amounts or plastic returnable pallets which can be used plenty of times. In case of needing any clamping and tensioning systems we recommend belts and bioplastic covering. In addition, we propose the use of big and returnable boxes and crates.

In Annex II, a list of success cases of sustainable packaging in the food supply chain has been compiled. These case studies have been classified in four main groups: use of bioplastics, replacing multilayer with monolayer plastics, replacing plastic with paper or cardboard and returnable packaging.

6. Conclusions

As it has been studied in this document, there are lots of different aspects to consider and lots of different actions we can implement in the food supply chain in order to achieve the principles of circular economy.

In this research, a hierarchy of the rules to be followed for the reuse and recycle of food waste has been proposed. However, this hierarchy is not strict, and, in order to implement the most appropriated ones, the particular aspects about each situation should be considered.

As well as that, an extensive list successful cases and guidelines to follow which can be helpful when planning a sustainable packaging strategy. However, it does not exist one way for the sustainable packaging and most of the times, not everything in the supply chain can be implemented at the same time. It should be considered in which stage of the supply chain each company is, which kind of food it is being produced, selling or distributing, its requirements and, of course, the economic aspects about it. Each sustainable aspect or each sustainable action carried out in the supply chain will be a good point to start.

If all the aspects mentioned in this document are finally considered and implemented in each stage of the food supply chain, it would mean a big success. There will be always constrains and difficulties that must be handled, as the economic issue, the preferences and convenience of customers, the legislation or the availability of sustainable materials and products.

In the near future, legislative changes, technology advances and awareness in civil society will modify the way our society will organize and the way we will deal with environmental aspects. For sure, the recycle and reuse of food waste and packaging are ones of the issues the society will have to reconsider.

7. Measurement of impacts

According to the description of the task, a measurement of the impacts of the different options of reusing and recycling would be provided, using the tools developed in task 1.2. By the time of developing this document, the mentioned tools are not ready available, therefore, the measurement of impacts will be performed and provided in a later stage, included in D1.2: Report on sustainable (environmental, social and economic) impact analysis.

8. References

[1] European commission. Plastic Waste in the Environment. 2011. doi:KH-31-13-768-EN-N.

[2] AMC. Plastic packaging resins. 2007.

[3] Plastics Europe. Plastics - The Facts 2017. 2016.

[4] EUBP. ACCOUNTABILITY IS KEY. Environmental Communication Guide for Bioplastics. 2017.

ANNEX I. Inventory of Successful Approaches to food waste reuse and recycling

The main conclusions of the successful approaches collection. However, it is also important to present them individually, in order to get a more specific idea of each one and which are the different actions carried out in order to achieve a common objective. The successful approaches identified has been identified in the following sectors:

- Meat sector
- Beverage
- Dairy
- Bakery
- Fruits and vegetables
- Cross to all
- Others

The information has been collected in a template, where a summary of the project is shown with the main information of it.

I.1. Meat sector:

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	EfficientHeat
Type of project:	Nutrient recovery for recycling and reuse in pig sector
Description of the project:	The overall objective of EfficientHeat is to offer to the EU pig farmers and external waste management agencies an integrated solution to reduce the pig slurries volume, reduce waste management costs, minimize pollutants emission and optimize total process energy consumption. It is achieving by developing a new evaporation technology and better processes for volume reduction of pig manure during the treatment process. EfficientHeat plant is a definitive integrated and efficient solution where the abatement of emissions (like N-compounds) also allows for the reduction of foul odours, one of the main complains from the population near pig farms. EfficientHeat is aimed at developing an integrated and cost-effective solution to reduce the volume of pig slurry, minimize the pollutant emissions and process energy consumptions. The main technology to be used here is the special version of the Unicus for evaporation applications. Unicus is a scraped surface heat exchanger for high fouling and viscous fluid applications. During evaporation, the scraping action keeps the heat transfer surface clean and maintains heat transfer high. This allows the evaporator to concentrate to levels where traditional technologies

	fail. This makes this heat exchanger the ideal solution for concentration of environmental waste where volume reduction is vital. On this project, the current scraped surface evaporation technology to treat pig manure is being optimized and better ways to increase the performance of the evaporators and make them more economical, are being developed, so the investment for pig farmers can be reduced. By applying the EfficientHeat technology pig farmers will be able to overcome the current obstacles in the sector by obtaining the following benefits: - Recovery of nutrients (nitrogen, magnesium and phosphorous) as fertilizers (valuable by-product). - Diminishing ammonia atmospheric emissions and therefore fulfilling EU water and air regulations. - Inhibiting fouling and therefore, reducing maintenance cost. - As a result, reduction of the total slurry management cost and therefore increasing the profit margin of the end user. The final system developed and validated is composed of the following elements or processes: - Struvite (Magnesium Ammonium Phosphate – MAP) precipitation system. - Innovative heat exchanger with ultrasonic system for fouling abatement. - Ion Exchange [IE] treatment for the removal of residual ammonia in the condensate after evaporation.
Location:	Spain
Timing:	10/2011 – 09/2013
Global budget invested in the pilot:	Total cost: 1.372.637,80€. EU Contribution: 1.084.300,00 €
Agents involved:	Logistic sector, pig farm sector, waste management.
Main results achieved: - CO_2 savings: 20% in comparison with the baseline - Energy savings in consumption: 20% in comparison with the baseline	
Interesting links:	http://www.efficientheat.eu/ https://cordis.europa.eu/project/rcn/100335_en.html

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	Use of biodiesel by-products (glycerine) in pig feeding
Type of project:	Use of by-products in animal feeding
Description of the project:	The objective of the project has been to study the nutritive value and levels of inclusion of the glycerine from the production of biodiesel in pig feeding. The quality of the glycerine produced in biodiesel plants has been studied in Spain. It has been analyzed the effect of the incorporation of glycerin on the manufacture of granulated feed and finally tests have been carried out on

	pigs during the whole bait where its effect on the digestibility of nutrients has been controlled, parameters productive and quality of meat. The incorporation of glycerin in the feed increased the production speed (P = 0.007) and the speed of the feeder (P = 0.002), being the linear effect (P <0.05), so the greater amount of glycerin added the higher the speed is. This indicates that the addition of glycerine improved the flow in the granulator, which could be related to a greater fluidity of the granular mass and a decrease in the friction forces in the granulator matrix. As a consequence, an improvement in production efficiency was observed when adding the glycerin, that is, the energy used to produce one ton of granulated feed decreased by adding glycerin (P = 0.013), also observing a linear effect (P <0.05) for this parameter. Specifically, the energy used to produce feed with 0, 2.5 and 5% of glycerin was on average of 31.5, 25.6 and 25.09 kWh and t, respectively, which it would mean a saving of more than 18% of energy. Glycerin from biodiesel plants with a glycerol content of 86% can be incorporated in pig feeding up to 5% to replace corn, without affect the digestibility of nutrients, the productive parameters of the animals or the quality of pork meat. In addition, it supposes an energetic saving superior to 18% in the process of granulation.
Location:	Lorca, Murcia (Spain)
Timing:	2008 – 2011
Global budget invested in the pilot:	Total cost: 1.061.756,99 €
Agents involved:	Centres of Innovation and Technology, pig farm sector
Main results achieved: - CO_2 savings: More than 18% - Energy savings in consumption: More than 18%	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	HYDROBLOOD
Type of project:	Reuse and recycle of pig waste
Description of the project:	Our overall objective is to bring to the market a new solution which will not only reduce the environmental impact of blood produced in slaughterhouses but optimize the protein production process for animal and human feed purposes too, in a reliable and cost-effective way. According to the FAOSTAT (2016) website, approximately 1452 million pigs were processed worldwide for their meat in 2013. From these, 309 million pigs were processed only in Europe (mainly in Spain, France, and Germany). If we consider that 3 litres of blood can be collected from each pig, the annual

	available blood supply can exceed 927k tonnes of blood in Europe and 4.35 million tonnes worldwide. With current technologies available into the market, only around 7% of the protein content in blood can be recovered. From AZUARA we have identified the business opportunity behind this market weakness, and we have developed the HYDROBLOOD processing plant to solve it. With our innovative processing plant, the whole content of protein can be recovered from animal's blood. Moreover, HYDROBLOOD will reduce significantly the environmental impact, since it does not need refrigeration nor heating installations, it generates almost no zoo-technical blood, and it reuses the total waste water generated. It will make a revolution within the meat sector, since the slaughterhouses will not only avoid the treatment of a high polluting waste (and its associated costs) but convert it into a high added value product that will suppose an increase by around 5% in their annual turnover. HYDROBLOOD processing plant produces 200g per litre of blood of Decolourised Hydrolysed Protein (DHP), a high-quality blood by-product with 95.85% of protein content and a high digestibility (99.54%), which will make a difference in the feed additives market, valued at 14,220 M€ in 2013, and estimated to reach 20,000 M€ by 2020 at a CAGR of 4.2% over the period 2013 to 2020.
Location:	Tarragona (Spain)
Timing:	07/2016 – 12/2016
Global budget invested in the pilot:	Total cost: 71.429,00€. EU Contribution: 50.000,00 €
Agents involved:	Meat production sector, waste management
Main results achieved: - High-quality blood by-product with 95.85% of protein content and a high digestibility (99.54%)	
Interesting links:	https://cordis.europa.eu/result/rcn/196302_en.html http://www.talleresazuara.net/news-en/71/new-project-from-talleres-azuara-hydroblood

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	ManureEcoMine
Type of project:	Green fertilizer upcycling from manure: cows and pigs
Description of the project:	European pigs and cows jointly produce about 1.27 billion tonnes of manure per year, a largely unexploited resource of organic carbon and nutrients. ManureEcoMine proposes an integrated approach to the treatment and reuse of animal husbandry waste, by applying the eco-innovative principles of sustainability, resource recovery and energy efficiency. Anaerobic digestion, ammonia stripping, struvite precipitation and partial nitritation/anammox will be key technologies that will be combined to demonstrate their technological and environmental potential at pilot scale for cow and pig manure. To render the cradle-to-cradle approach complete, the

	fertilizer and potential trace contaminants effects of recovered nutrients on plant growth and soil health will be established. and Life cycle analyses economic viability will determine the sustainability of the concept as such and identify the most environmentally friendly technology and most effective and safe reuse strategy. Risk management will be developed with regard to trace contaminants for guaranteeing safe handling and high product quality for a closed nutrient cycle. Pilot plant: - Anaerobic digester - Decanter Centrifuge - UF membranes - Struvite reactor - BNR reactor
Location:	Spain, Netherlands
Timing:	11/2013 – 10/2016
Global budget invested in the pilot:	Total cost: 5.496.455,30 €. EU Contribution: 3.799.740,45 €
Agents involved:	Centres of Innovation and Technology, meat production companies, waste management companies
Main results achieved: N/A.	
Interesting links:	https://www.manureecomine.ugent.be/

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	METABIORESOR
Type of project:	Energy recovery and waste reduction in the meat sector
Description of the project:	METABIORESOR built, validated, demonstrated and disseminated an innovative system for the management of different residues and by-products coming from the agriculture sector (pig farming) and cities. The project main objective was to validate an innovative system for the management of residues and assess its potential if applied at large scales. The main activities of the project consisted on: - To build, in the municipality of Lorca (Murcia), a pilot plant that included the prototype of the management system; - To test and validate the individual parts of this prototype and to develop two complete cycles of the system in order to assess its performance. - To develop an additional management practice, including only the hydrolyzation stage, at farm level (in a farm belonging to the partner ALIA) in order to validate and demonstrate in a much closer approach to farmers the management system. - To develop different communication activities for both professional and general stakeholders in order to disseminate the project activities and outputs and to facilitate the transfer and implementation of this solution to other areas.

	Pilot plant with: - Hydrolyzing tanks - Biogas plant - Evaporator-dehydrated - Crusher of woods and branches - Mixer - Pelletizer - Biomass boiler Modifications in the legislation are the main encountered barriers for its wide spreading.
Location:	Lorca (Murcia)
Timing:	06/2010 – 12/2015
Global budget invested in the pilot:	Total cost: 2.645.308,00€. EU Contribution: 1.231.913,00€
Agents involved:	Municipality of Lorca, agriculture sector (pig farming), meat production sector
Main results achieved: - Potential CO_2 savings: More than 75% - Waste addressed: 36,4 t/y - The only final residue is ash, which has multiple applications as raw material	
Interesting links:	http://metabioresor.eu/

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	NOSHAN
Type of project:	Recycling project. Animal feeding.
Description of the project:	The main focus of NOSHAN is to investigate the process and technologies needed to use food waste for feed production at low cost, low energy consumption and with maximal valorisation of starting wastes materials. Nutritional value and functionality according to animal needs as well as safety and quality issues will be investigated and addressed as main leading factors for the feed production using food derived (fruit/vegetable/plant and dairy). Food wastes are characterized for their nutritional potential, but also suitable technologies to stabilize them and convert them into suitable raw materials for bulk feed will be investigated. Obtaining functional feed ingredients (additives) from these wastes will also be targeted as it is an important factor determining final feed cost and functionality in animals. Two different groups of activities will be thus addressed: - Replacement of bulk feed ingredients (constituting up to 90-95% of feed weight) with starting waste materials to cope with part of the huge amounts of food waste generated in Europe.

	- Valorisation of active ingredients as well as the upgrade of waste into more valuable feed additives will be studied. The later constitute approximately the half of the feed cost.
Location:	Several countries in the EU
Timing:	08/2012 – 01/2016
Global budget invested in the pilot:	Total budget: 4.075.842,40€. EU Contribution: 2.999.257,00€
Agents involved:	Centres of Innovation and Technology, waste management companies, recycling companies, companies in the chemical sector, companies in the nutrition sector
Main results achieved: - Potential CO_2 savings: If 1 % of total chicken broiler feed in Europe was switched to the 10 % NOSHAN mix diet, the total amount of CO2 emissions avoided would be 0.62 million tonnes each year un the EU. With a NOSHAN 10 % mix diet, for every kilogram of broiler chicken feed, carbon dioxide emissions were reduced by 0.3 kg compared to a non-food waste diet. - Potential energy savings in consumption: For Refractive Window Drying technology: Total energy requirement / kg product = 0.675 kWh/kg product (steam) + 0.3309 kWh/kg product (electricity) = 1 kWh/kg product = 1000 kWh/ton. Up to 30% energy reduction is possible after optimization of planetary roller extruder and RDW technologies. - Potential waste addressed :10% of piglet and broiler feed with NOSHAN mix diet. - Potential waste reduction: Assumption of 1% of total broiler and piglet	
Interesting links:	http://www.noshan.eu/index.php/en/

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	PigHeat
Type of project:	Treatment of meat by-products
Description of the project:	BIGAS ALSINA, a family owned company specialized on machinery manufacturing for the Food sector, aims to commercialize PigHeat, a novel technology that allows processing pig fur and pig roughing. Right now, pig fur and roughing are simply dried in order to reduce weight and volume and used as fertilizer in landfills. In other words, pig meat processing means that there is a waste that actually needs to be disposed of, which is the least desirable effect of waste. Not only does pig meat processing incur waste disposal, it also implies an important investment in energy to remove water as well as removal cost. This cost is directly paid by the slaughterhouse. Through the proposed PigHeat processes, pig fur and roughing can be used as an alternative source of fuel that creates steam and service water instead of using gas, diesel or electricity. The meat processing industry consumes high amounts of energy. By using pig fur and roughing as fuel, an environmental waste problem is transformed into an important way to save 15% of heating

	energy, while promoting waste valorization and a circular economy within the sector. This is achieved in 4-steps: i) homogenization, ii) hydrolysis, iii) drying and iv) combustion. The obtained product is a CO_2 neutral biomass with exceptionally high heating value (even higher than wood pellets) that can be used in the daily operations of the same installation. Due to the stringent waste regulations, the 1,700 medium sized slaughterhouses in Europe are looking for a solution. Not only that, they are operating on very low margins and PigHeat will allow them to cut energy expenses, thereby increasing profits. Buying PigHeat implies certain costs for slaughterhouses, however the savings will fully have paid for the machinery in less than two years. For the implementation of the project t is needed the Creation of an industrial plant to transform pig fur and pig roughing into fuel to be used in a biomass steam generator or biomass hot water boiler.
Location:	Spain
Timing:	11/2016 – present
Global budget invested in the pilot:	Total cost: 1.984.566,25€. EU Contribution: 1.389.196,38€
Agents involved:	Meat sector, Waste management
Main results achieved: - CO_2 savings:15% - Waste addressed:100% of the by-product	
Interesting links:	https://cordis.europa.eu/project/rcn/205883_es.html

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	PILOT-ABP
Type of project:	Reuse and recycling project. Meat sector.
Description of the project:	PILOT-ABP project aimed at developing new eco-innovative technologies associated to the animal by-products process, which allow on the one hand an environmental improvement of the process, thanks to a more efficient consumption of the energy used in the process and a better recovery of raw materials, with a related decreasing in wastes production, and on the other hand an increasing of the added value of the obtained products which leads to a better financial profitability of SMEs. In this sense, within PILOT ABP project the feasibility of the several processes and products has been demonstrated at semi-industrial scale through the design and construction of three pilot plants where the operation conditions have been also optimised. More precisely the following marketable results have been achieved:

	- Hydrothermal liquefaction (HTL) pyrolysis as new technology for valorisation of ABP wastes where a biocrude with high caloric value is obtained, as an alternative renewable energy source - Short path distillation (SPD) as new technology for valorisation of fatty acids to obtain high value oils for different applications, such as food and pet cosmetics. - Enzymatic hydrolysis as new technology for valorisation of processed animal proteins (PAP) allowing the production of a broad range of collagen-based products as biopolymers with high market demand, for different intended applications (functional chemicals, fertilisers, etc.) What is more, Pilot-ABP project represents innovative business opportunities. A wide range of industrial applications for each pilot plant have been identified. Initially main sectors of application will be those covered by the participant SMEs, but all of them believe that there will be an increase in their products portfolio in the short and medium term, with innovative industrial applications and products thanks to the results of the project.
Location:	Denmark, Italy, Spain.
Timing:	06/2014-05/2017
Global budget invested in the pilot:	Total budget: 2.642.117,00 €. EU Contribution: 1.789.323,00€
Agents involved:	Centres of Innovation and Technology, meat production companies, recycling companies, companies in the chemical sector
Main results achieved: - By-products used to get high added value products	
Interesting links:	http://pilot-abp.eu/es/

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	PLAGASMIC
Type of project:	Gasification of pig and cow manure for cost-effective biogas generation
Description of the project:	The livestock sector in Europe is facing a problem: The manure it generates cannot all be used as fertiliser because excessive amounts of manure to land can lead to surface and ground water contamination through the accumulation of minerals in the soil, as manure contains high amounts of nitrogen and phosphorus. The EU has legislated to place severe restrictions on the quantity of organic manure that can be applied to land (170 kg N/ha/year). Farmers are facing increasing costs to export manure off-farms the current level of spread lands is inadequate to meet the limits. There is an urgent need for the livestock farming community to develop a method of removal and reuse of animal manure such that the economic and legislative burden on them may ease through the development of an environmentally-friendly technology. Current technologies require very high capital investment that is out of reach of most of the farming community. Our project involves the pyrolysis of manure using

	microwave induced plasma (MIP) technology allowing a rapid release of biogas. The implementation of the project requires the construction of a plant for pyrolysis of manure using microwave induced plasma (MIP) technology allowing a rapid release of biogas.
Location:	Liverpool (United Kingdom)
Timing:	09/2012 – 08/2014
Global budget invested in the pilot:	Total cost: 1.482.071,20€. EU Contribution: 1.135.000,00 €
Agents involved:	Waste management, meat production sector, centres of Innovation and Technology
Main results achieved: N/A	
Interesting links:	https://cordis.europa.eu/result/rcn/165735_en.html

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	PROSPARE
Type of project:	Bioconversion of poultry meat&bone residues
Description of the project:	The animal by-products (AB-P) industry has always been a vital part of the world food production chain, providing valuable new products and reducing pollution loads. Anyway, the treatment of animal bioresources requires new and safe biotechnological tools and processes are developed. PROSPARE aims at developing a technological platform for multi-purpose processing of AB-P, in particular poultry ones, flexible enough to be tailored to different industrial sector needs. Using a novel biocatalytic approach unmarketable poultry secondary resources will be converted into value added peptide hydrolysates leading to marketable end-products, with programmable nutritional properties, and biodiesel. Innovative techniques will be used for the molecular characterization of the hydrolysates. Safety issues associated with new technologies will be properly addressed and novel methods to assess the healthiness of intermediate and end-products developed and compared to standard ones. Platform feasibility will be demonstrated by scaling up to pre-industrial pilot level. The technological innovations will allow obtaining a range of products with programmed functional properties and sensory characteristics that will appeal to consumer objective and subjective requests. Functional characteristics to be targeted will include antioxidant, prebiotic, antimicrobial, antihypertensive properties. The outcome of the PROSPARE project is likely to generate a significant technological breakthrough in the field of AB-P treatment. This will therefore have an impact on the current Regulatory Framework both in EU and RF. An important aim of the project is to prepare the ground for the evolution of the

	Commission directives in that context. Moreover, taking advantage of this international cooperation, recommendations on how to harmonise, in the longer term, both legislations will also be delivered to the Commission.
Location:	Italy
Timing:	09/2008 – 08/2011
Global budget invested in the pilot:	Total cost: 3.694.460,00€. EU Contribution: 2.670.555,00€
Agents involved:	Waste management, meat production sector, centres of Innovation and Technology, public administration for international cooperation
Main results achieved: N/A	
Interesting links:	https://cordis.europa.eu/project/rcn/87819_en.html

I.2. Beverages:

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	CANVAS
Type of project:	Transformation of the spent grains of the brewing process for human nutrition.
Description of the project:	In the brewing process, sugars from barley are removed, the resulting grains are a residue with nutritional value but perishable. The spent grains can be directly used to feed animals but as they decomposed fast they are easily dumped. In order to transform spent grains in a high-added value products AB InBev's developed an innovative process. Firstly, using a lactic acid fermentation process spent grains are convert into stable food ingredients. Secondly, innovative technology was developed to release the nutritional value from the plant ingredients. The last step was connected and scale up all the process. This process was used to create a shake rich in fibre and protein suitable for human nutrition. Spent grain isolate represents about half of the liquid in the final shake; other ingredients include coconut milk, cashew milk, pea protein isolate, chicory root extract and flavours. The product is pasteurized, requires refrigeration and have a 90-day shelf life. A pilot plant was built in a retrofitted shipping container-cum-production facility inside AB's Newark, N.J. brewery, so the fermentation process can be applied immediately after the grain comes out of the tank. This system could be integrated into more breweries in the future. Canvas, the spin off in charge of its production and commercialization, launches a crowdfunding campaign of $25,000 goal, having raised over $39,000.
Location:	Process developed in AB InBev's Global Innovation and Technology Center (GITeC) in Leuven, Belgium. Fist scale plant created in United States by Canvas.
Timing:	Following its release on the US East Coast, the West Coast will follow and if reactions remain positive, AB InBev will introduce the drink in Europe. A plant closer to the brewery in which the fermentation process takes place.
Global budget invested in the pilot:	No data available
Agents involved:	AB InBev and Canvas
Main results achieved: - Potential CO2 savings: AB InBev can potentially reduce carbon emissions approximately 5,000 tons per year through an industrial-scale implementation of this technology in Europe 75% reduction in CO2 emissions.	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	SPENT GRAIN SUB-PRODUCT USE AS FOOD FOR COWS
Type of project:	N/A
Description of the project:	A sub-product of the brewing process are the spent grains, it the waste resulting of removing sugars from barley. For each 10 litters of beer 2kg of spent grains are produced. This sub-product has a high protein content (around 25%) and can be feed directly to animal but it decomposed fast and is easily dumped. Damm is a beer producer in El Prat de Llobregat (Spain) and the 100% of its spent grains (90.000 tons annually) are distributed to feed animal in the farms close to the brewery. Other breweries, as Mahou- San Miguel, report similar % or reuse of the spent grains with the same purpose.
Location:	N/A
Timing:	N/A
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	http://www.higienealimentaria.com/jornada%20san%20miguel/Informacion%20Grupo%20Mahou%20San%20Miguel.pdf

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Water Houses (Casa dell'acqua)
Type of project:	In the beverage sector water houses avoid one use bottles of water
Description of the project:	Water Houses systems were installed in Italy, in the provinces of Milan, Monza Brianza, Sondrio, Lodi y Pavía, Lunigiana, Ariccia, Andria, San Benedetto del Tronto, Roma y Gallipoli. In 2012 Lombardía has 244 water houses among a total of 411 in all Italy. These systems are normally installed by a municipality but they can also be promoted by a neighbourhood or a church. Water Houses supply water, natural or sparkling, refrigerated or not. Water is obtained from the supply network and is treated and filtered. The cost for the user is normally zero but also a small charge can be applied. This system replaces the consumption of mineral water. Thus, It eliminates the production and distribution of millions of plastic bottles, reducing the emissions of CO2 and the generation of wastes.

	One Water House cost 9000 euros and in a year, it supplies 600.000 litters of water, saving 400.000 bottles of plastic with is equivalent to 16.000 kg of plastic, which need 46.000 litters of petrol for its production and transport saving 50.000 Kg of CO2. Each year in Lombardia this system saves 16.000.000 of bottles of 1.5 litters which make a total of 350 tonnes of plastic. Furthermore, the reduction in the road transports supposes less CO2 emissions. This system is adapted to a municipal water supply source.
Location:	Italy
Timing:	They widespread around 2012
Global budget invested in the pilot:	9000 euros per municipal Water House
Agents involved:	Municipalities or communities.
Main results achieved: - CO_2 savings (tCO_2): 50.000 Kg of CO2 per machine per year. 46.000 litters of petrol. 400.000 bottles of plastic per machine per year.	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	WET WINE
Type of project:	Pilot plant for the treatment of the waste generated by the wine industry
Description of the project:	WETWINE Project: "Transnational cooperation project to promote the conservation and protection of the natural heritage of the wine sector in the SUDOE area" tackle the problem of the water waste generated by the wine industry recycling the solid fraction as a fertilizer, reducing the impact of winemaking by 90% over the natural heritage. Various process and operation carried out during wine production generates large volumes of wastewater, with highly variable flows and loadings. Constructed wetland systems constitute an alternative to conventional systems due to their low cost and low energy requirement. A pilot plant that perform anaerobic digestion and wetland treatment of water and sludge at Santiago Ruíz Winery (El Rosal, Pontevedra) was constructed. It consists of an anaerobic hydrolytic up flow blanket reactor (HUSC) (1.25 m3 useful volume), a vertical subsurface flow constructed wetland (VFCW) (30 m2), a horizontal subsurface flow constructed wetland (HFCW) (30m2), and a one-stage sludge treatment wetland (STW) (20m2). In this case, wastewater is reused for irrigation and sludge produced is valorised as fertilizer. LCA analysis comparing WETWINE with a conventional wastewater treatment plant* shown that the potential environmental impact of the WETWINE system is between 2 and 12 times lower than that generated by a conventional system. *Conventional wastewater consists of a conventional pre-treatment and an activation sludge reactor with extended aeration followed by a secondary settle. Treated wastewater is then discharged into the public sewer system

	and treated in a municipal wastewater treatment plant in order to meet the discharge limits set by the regulation
Location:	El Rosal, Pontevedra
Timing:	Project duration is from July 1st, 2016 until June 30, 2019.
Global budget invested in the pilot:	No information available
Agents involved:	A wine producer
Main results achieved: LCA comparison of this pilot plant with a conventional system results the reduction of the following impacts: - 50% in climate change - 55% in ozone depletion - 92% in freshwater eutrophication - 38% in metal depletion - 52% in fossil depletion	
Interesting links:	N/A

I.3. Dairy:

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	Acid whey
Type of project:	Use of a by-product of dairy products otherwise considered a waste.
Description of the project:	Acid whey is generated during the production of a number of dairy products, the most famously Greek yoghurt, but also a number of cheeses, like cottage or cream cheeses, and quark. Yields for some of these dairy products are typically only 25-50% of the milk used. In the case of Greek yoghurt two thirds of the milk needed finish as acid whey. Acid whey can cause environmental problems if is not properly disposed. It can be limited landspread as fertiliser or use as animal food. Compare to sweet whey, acid whey contains a lot less protein and is more difficult to work with because it turns into a sticky mess when it´s dried down. Acid whey contains lactose, lactic acid, calcium, phosphorus and galactose. Some companies have invested in anaerobic digesters to convert acid whey into methane, or in filtration systems to remove water from the acid whey so it is easier to transport. More than 3500 patents were published from 2012 to 2017 with most of the work focussed on extracting valuable ingredients. Arla Foods developed a product, Nutrilac® whey protein solutions, that is added to the acid whey and make possible to transform it into other dairy products, enabling to use 100% of the milk and avoiding the waste. Possible applications include cream cheese, processed cheese, dips, beverages, stirred yoghurts and desserts. It's estimated that Greek yogurt manufacturers in the US generate about 1 million tonnes of acid whey every year. But simply by adding Arla Foods Ingredient's unique Nutrilac® whey protein to a mixture of acid whey, water and cream, dairy companies can create a high-quality dip that is typically only 6% fat and contains 4% protein. The finished product is very stable with a shelf life of about six months, and is typically 6% fat and 4% protein. Thus, this process enables manufactures to produce value-added dairy products (as fermented beverages, whey smoothies and fermented desserts) from their acid whey. Furthermore, this solution eliminates the storage and transport requirements associated with other methods of disposing the acid whey.
Location:	N/A
Timing:	Develop in 2013
Global budget invested in the pilot:	N/A
Agents involved:	Dairy products manufacturer and the seller of the solution.
Main results achieved: N/A	
Baseline:	N/A

Interesting links:	https://www.arlafoodsingredients.com/about/press-centre/2016/pressrelease/acid-whey-isn-t-waste-it-s-a-goldmine-says-arla-foods-ingredients-1422934/

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	BIOPROTECTION OF YOGURTS AND CHEESE
Type of project:	*Addition of food cultures to preserve shelf life and reduce food waste of yoghurts and dairies*
Description of the project:	Perishable products like dairy contribute to higher levels of food waste. 20% of all EU dairy products are wasted. This is equivalent to 29 million tons a year. 17% of all yogurt goes to waste and 80% of the total yogurt waste happens because its use-by-date expires in the supply chain. Some companies commercialise selected cultures able to delay spoilage from contaminants such as yeast and mold. Some commercial examples are FreshQ® or HOLDBAC®. FreshQ® is able to extend shelf life in yogurts an average of seven days. HOLDBAC® is able to extend shelf life by a factor of 3 in white cheese. These cultures are added to the milk together with the starter culture before starting the process of production of yogurt or cheese. It has a cost and a reduction of food waste means reduction in demand. These were the main barriers encountered for its wide spreading.
Location:	N/A
Timing:	FreshQ® was commercialised in 2013.
Global budget invested in the pilot:	No information available
Agents involved:	Yogurt or cheese manufacturer and the producer of the cultures

Main results achieved:

- Baseline: 20% of all EU dairy products are wasted. This is equivalent to 29 million tons a year. There is not data of the currently implementation of the cultures.
- Potential CO_2 savings (tCO_2): 400,000 tons of CO2 if applied to white cheese globally
- Potential waste reduction: 22000 Tons of yogurts in Europe and 30% annual reduction in yogurt waste

Interesting links:	https://mejeriteknisk selskab.dk/sites/default/files/MejeriteksniMejeriteksnikSelskab/malene_svejstrup_vers._2_-_bioprotection_of_cheese_-_possibilities_and_experiences_-_dupont_final_5-12-17.pdf

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Milk automat machines
Type of project:	Milk sector
Description of the project:	Raw milk vending machine is a mechanism, which dispenses milk automatically, once the customer inserts money into the machine. Mild vending machines provide milk directly from a local farm to the final consumer 24 hours a day. Customers can bring their own containers or purchase a reusable glass or plastic bottle. Milk can be unpasteurized or pasteurized. The machine automaticatly text the person in charge and stops vending if the refrigeration stops working. Unpasteurized milk is the most spread type. In this case the milk is changed daily and the leftovers can be sold to local grocers to make other dairy products. The dispenser has a self-cleaning spout that is sterilized with a UV light between purchases. The milk can be sold in increments of 20 centilitres so there is no need of any leftover. A research report (Raw Milk Vending Machine Industry in Europe: Forecasts to 2024) states that the Europe raw milk vending machine market was worth worth US$6.45 mn in 2015 and is growing. In 2015 421 units or raw milk vending machine stood in Europe, this is expected to increase to 1252 units by 2014. Italy has shown a high rate of adoption with currently 1028 vending machines. Milk vending machines can be installed in the street, shopping center, supermarket, schools, factory or farms. The prime players operating in the raw milk vending machine market in Europe are Brunimat GmbH, ProMeteA S.R.L., Letina Inox D.O.O., DF Italia S.R.L., Risto Gbr (Risto Vending), The Milk Station Co. Ltd., and Milk Automation S.R.O 50,000 euros per machine in France but depends on the model. The sale of unpasteurised milk is forbidden in some countries but the machines can also sell pasteurised milk (as some cases in Spain). This is the main barrier encountered for its wide spreading.
Location:	France, Croatia, Switzerland, Austria, the Netherlands and Italy
Timing:	First implementations are reported before 2010.
Global budget invested in the pilot:	N/A
Agents involved:	It can be implemented directly by a farmer or foster by a community or a grocery store.

Main results achieved:

- Baseline: A national brand milk generates 0.1146 kg of CO2 emissions in the transport of 1 litter of milk.

- A farm located 120 Km away of the vending machine generates 0.0670 kg per L of milk (Torquati, Taglioni, and Cavicchi 2015). In addition to the plastic avoid if consumers reuse its bottles.	
Interesting links:	http://www.lattecrudo.info/index.php?lang=en

I.4. Bakery:

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	Demonstration plant project to produce Poly-Lactic (PLA) biopolymer from waste products of bakery industry (BREAD4PLA)
Type of project:	Recycling of bakery wastes to obtain 100% biodegradable and compostable plastic packaging for bakery sector.
Description of the project:	The main objective is to demonstrate, in a pre-productive pilot plant process, the viability of poly (lactic acid) (PLA) synthesis from waste products of bakery industry, by means of a 'clean' enzymatic biotechnology, and their use in the fabrication of a 100% biodegradable film to be used in the packaging of bakery products. The overall results from the demonstration project prove that the bakery waste is a suitable raw material that can be an actual environmentally friendly alternative to obtain 100% biodegradable and compostable plastic, with satisfactory performance for bakery products such as bread, biscuits and shortbreads observing that it can be used in bakery products. It is important to emphasize the good behaviour in products such as shortbreads because of their composition and moisture content, being well suited because of the characteristics provided by the new material The fermentation of waste bread allows the production of 0.35 kg lactic acid per kilogram of bread, which is same range as for other feedstocks. Regarding the production of PLA, yields at this small pilot plant have been around 50%. From the same lactic acid, the yield in industrial process will be at least 77% based on data from pilot trials. So, depending on the scale, one kilogram of bread can be converted to 0.175 and up to 0.25 kg of PLA. In addition, in both processes, LA and PLA production, some points have been detected to be improved and the yield would increase, being more feasible to make improvements on a large scale, mainly based on purification processes. From the data provided by different big bakery companies in Spain and UK, around 25% of the bakery waste produced by them could be intended to the production of PLA packages. The rest is derived to animal feeding. Considering the yield figures estimated, the recovery of the bread waste generated for a single bakery big company could lead to the production of 680 ton/year of PLA, replacing the equivalent amount of conventional plastics in the bakery sector at a competitive cost. Energy savings in consumption (%): Installation for fermentation processes for LA production. It is easy to adapt the conventional extrusion equipment to the PLA biopolymer (as for the commercial grades already available). The main barriers encountered for its wide spreading were: - Substrate must be available in significant quantities. - No seasonality of supply, to have a constant supply of the substrate during the whole year. In the case of bakery waste, it can be assured a constant supply. - Origin of the bread waste, being very important to collect the total amount required from the same bakery plant. This would help to simplify logistic and

	diminish transport costs, as well as guarantee a constant composition and quality of the bread waste.
Location:	N/A
Timing:	2011-2014
Global budget invested in the pilot:	Duration: 36 months · Budget: 1,116,526 € (of the entire project) It is very difficult to estimate the costs of fermentation processes for LA production and the costs reductions by optimizing the process due to the fact that the study has been performed at pilot scale. The same happens with the polimerization process to produce PLA from LA. Data, figures, etc. about larger scale processes are not available as they are considered confidential.
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Case study of Food bank
Type of project:	This is an example of food reusing project. Unsold loaves are handed over to consumers through a system of Food banks.
Description of the project:	Unsold bread along with other foodstuff is redistributed through a system of Food banks operating in local communities. Food Banks are non-profit organisations having the status of association or foundation. Food Banks are autonomous institutions. The activities cover: — Identification of food sources produced in over abound — Sequestration of food, including products with a short shelf life, non-tradeable articles, faulty packed and the nutritional value is not questionable — Storing of the food and rational distribution for the organisations — Promotion of attitudes preventing utilisation of food or its waste In 2017 Food Banks in Poland supported 1 447 844 people in the need, handing over 65 500 tons of food for social purposes through 3 342 organizations and social institutions: eateries, community day care center, spikes and night care houses, educational centers, hospices, centers supporting women solely rearing children, orphanages and other institutions. Bread constitute around 10% of the unsold food. Cost structure: Investment cost — Cost of adaptation of storage areas. Example for Jarczewo gmina in Poland. Cost 5000 Euro. Operational costs: — Cost of acquisition and distribution of the food

	— Administrative costs — Promotion and education Staff work to some part is volunteer work. Examples of support from local government is around 100 000 Euro (cities: Ciechanów, Kielce, Olsztyn, Wrocław). The main barriers encountered for its wide spreading were: - This approach needs collaboration and facilitating good contacts with society and organisations. - Fiscal issues: — release from VAT for food handed over to public organisations for charity purposes — accounting of the food donation as cost of revenue earning – CIT deduction, relieve from waste utilisation In Europe there are changes in legislation favouring transfer of the unsold food between producers and sellers to the charitable organisations. In some countries France and Czech Republic transfer of the unsold food is obligatory. Similar law is considered in Poland This solution has also negative aspect for the food banks because of manageability of the food stream. The logistic problems are solved through development of management schemes based on the Barcode.
Location:	Common approach in Europe: Food Banks operates as non-profit organisations
Timing:	On-going activity
Global budget invested in the pilot:	The measures from the case study are cost-free.
Agents involved:	The solution has a system character. Food banks operates as non-profit organisations. They are supported financially by local governments and other charitable institutions, markets and shops should be involved. Involvement of volunteers is important. The activity has to be supported by the legislative bodies and control agencies, local public organisations and public services: social care. There are numerous examples of food relaying of unsold food to non-profit organisations. In Poland KFC program for chicken products handed over to. Caritas, MONAR-u, Stowarzyszenia Brata Alberta.
Main results achieved: N/A	
Interesting links:	N/A

CIRC4Life	**Inventory of Successful Approaches to food waste reuse and recycling**
General Information	

Project title:	Case study of Riverside Sourdough bakery.
Type of project:	This is an example of reusing project. Unsold loaves are handed over to consumers.
Description of the project:	Riverside Sourdough, small bakery, Cardiff, United Kingdom. Its bakers specialise in baking sourdough loaves using traditional methods. Each week, the owner of the bakery makes loaves to be sold at local markets and to local cafes. The bakery applies several measures in order to not waste the bread. Some surplus loaves are given to the activist organisation Food Not Bombs and some are donated to Cathay's Youth and Community Centre for use in its café. The bakery also has a list of customers who have signed up for leftover loaves. If there is spare bread that has not been sold at the end of the day, the people on the list are contacted and they can collect their loaves from the bakery and decide how much money they wish to pay when they arrive. The team also attends a local community currency meeting, which takes place once a month directly after the market. After leaving the market, loaves that haven't been sold are taken to these meetings to be exchanged for other goods. Finally, some bread can be frozen for future use.
Location:	Cardiff
Timing:	On-going activity.
Global budget invested in the pilot:	The measures from the case study are cost-free.
Agents involved:	This approach needs collaboration and facilitating good contacts with society and organisations.
Main results achieved: N/A	
Interesting links:	N/A

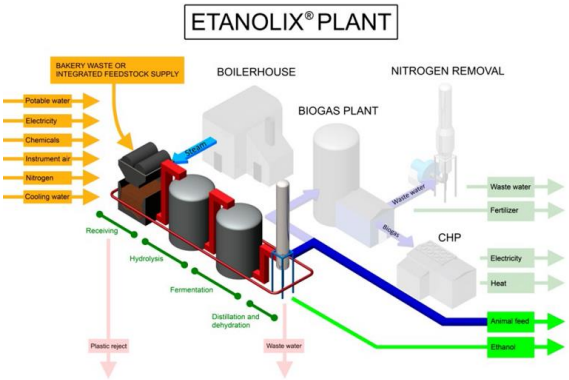
Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	The use of bakery wastes to production of bread crumbs
Type of project:	This is a recycling project carried out within bakery sector.
Description of the project:	Unsold bakery products are returned to the bakery for the production of bread crumbs. Bakery waste has to be safe for the health of consumers. The use, for secondary processing, of bread with signs of infection is absolutely unacceptable. The further processing should exclude products decorated with various types of sprinkles (poppy seeds, black cumin, caraway seeds, etc.) or with some additions to the dough e.g. grains of foreign cereals. Only the bread with shape defects and mechanical damage as well as stale bread, which, for various reasons, has not left the bakery, can be used for secondary processing. In the case of food control, the entrepreneur has to confirm that the Unsold bakery products meets the quality requirements, in particular microbiological ones. The time for safe storing of the unsold bread is generally up to 7 days. Most often such processing concerns the production of breadcrumbs and the addition of a small part of such bread (in proportion to a few percent in relation to the flour used) for dough for basic

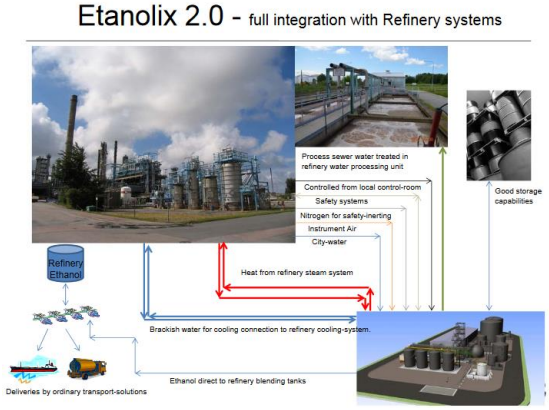
	and whole-grain breads. For the preparation of crumbs bakeries use bread in following proportions: 80% of rolls and 20% of bread loaf. From 1kg of bread we can obtain, after drying, 70 dg of crumbs. This example is a common practice in Poland.
Location:	N/A
Timing:	If it was part of a project, dates and duration of the demonstration. If it is currently running, date of first implementation
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Etanolix
Type of project:	Recycling project
Description of the project:	St1 Biofuels Oy's bio-ethanol production plant produces ethanol utilising ligno-cellulosic biomass from three different waste streams, collected at smaller scale sites for conversion to ethanol to both minimise bulk feedstock resource transport and allow better utilisation of process waste heat. St1 utilises the Etanolix® processing concept for sugar and starch-rich waste streams, e.g. from breweries and beverage industries, bakeries, potato processing factories. St1 started ethanol production in Gothenburg in June of 2015, with an annual production capacity of around 5 Ml. The plant delivered to North European Bio Tech Oy (NEB) recycles feedstocks such as biowaste and process residue from local bakeries and bread from shops that is past its sell-by date into ethanol for transport fuel. Feedstock high in Carbohydrates includes: old bread, rest beer, excess dough, packed bakery products, unpacked bakery products, off spec brewery products, waste flour. Around 20,000 metric tons of bakery waste is used as feedstock annually. The Etanolix production process starts with receiving feedstock that has high carbohydrate concentrations, such as bakery waste. The feedstock may still be in its paper or plastic packaging, which is removed during the reception process. In the hydrolysis stage, the feedstock is diluted with warm water in order to convert it into slurry. Before the fermentation process, the mash is cooled down, after which yeast slurry and enzymes are added. During the fermentation process, carbon dioxide is formed and collected and then cleaned to recover ethanol traces.



In the distillation phase, the ethanol is removed from the fermentor beer, concentrated and then transferred to dehydration. The stillage that remains from the distillation process is collected for further use as animal feed or as feedstock for biogas plants. The final product is a high grade 99,8% ethanol. Thanks to its feedstocks and production technology, the ethanol produced at the Etanolix® plant will be almost carbon-neutral. The plant is fully integrated into the functions and logistics of the refinery, which will yield significant synergy benefits in the use of residual heat and cooling and in product distribution.



Based on data from St1 and literature, production costs for such a medium-scale production facility amount to 530 €/m3 of 100% ethanol, or 459 € when accounting for an average co-product value of stillage, which can be used as an input for animal feed. Production costs include investment costs and feedstock costs, as well as costs for electricity, steam and heat (utilities) and for needed chemicals, yeast and enzymes. Feedstock cost is one of the key considerations in a business case for biofuels. The expected revenue is estimated between 450 and 600€/m³, with an average of around 650 €/m3 expected in the longer term. Assuming a 'green premium' of approximately 50 €/m3 between fuel supplier and distributor, this model project would generate an internal rate of return of approximately 7.7%, with a payback period of around 9 years.

To ensure economic viability of the bio-ethanol plant, waste providers must be willing to:
- have a localised conversion facility set up on or close to their premises,
- provide the feedstock both continuously and at a reasonable price
Collecting bread and bakery waste requires considerable organisational effort for using existing or establishing new connection networks.
• Ensuring the supply with bread and bakery waste needed for bio-ethanol plants with an annual production capacity of 5–10 Ml requires cities of at least 500,000 inhabitants.

	Waste-based feedstocks are more attractive in price and price stability, but competitiveness vis-à-vis other biofuels or conventional fuels seems currently limited by »» less mature conversion technologies, and »» much higher capital expenditure (CAPEX) and operational expenditure (OPEX) than for crop-based ethanol production • Oil price (development) matters too, because »» it determines production cost of biofuel's' primary competitor, fossil transport fuels, and »» production costs of agricultural commodities strongly depend on and move with oil prices • High-blend ethanol fuels require changes to fuelling infrastructure and vehicle fleets; there is a lack of stimulus for the development of high ethanol blend fuelling infrastructure • Difficulties in developing upscaled and advanced biofuel refineries when private investors are hesitant, while government participation is limited. Lobbying influence from fossil fuel, automobile and food industries highlights the potential for damage to fuel systems and engines at 10% fuel blends, thus contributing to blocking legislation on 10% blends in a number of European countries • Remaining lack of clarity on financial stimulus and further competition with first generation biofuels; • Lack of stimulus for the development of high ethanol blend fuelling infrastructure; • Limited commodification (and trading possibilities) of blending mandate credits; investors lack price signals for the value of their waste-based biofuels, in particular
Location:	Gothenburg, Sweden
Timing:	St1 started ethanol production in Gothenburg in June of 2015
Global budget invested in the pilot:	Investment costs, feedstock costs, electricity costs. Steam and heat (utilities) and for chemicals, enzymes and yeasts. The price for bread and bakery waste is between 60 and 150€ per tonne.
Agents involved:	Small scale and localised plants to convert organic waste into bio-ethanol require connection networks to waste providers: Collection of waste from bakeries and bread products past their sell-by date from retailers is facilitated through the bakeries, other intermediaries, or set up by St1 specifically for the purpose of use in the Etanolix plants. Substrates are delivered from brewery and bakeries.
Main results achieved: - CO2 emissions are far lower than for fossil fuels or crop-based biofuels; comparing well-to-wheel fossil energy use in the case of maximum feedstock use waste-based ethanol allows potential GHG emission savings of 75.5 mt CO2-eq when compared with wheat-*based* ethanol and 110 mt CO2-eq when compared with gasoline; this is equal to circa 6.4 or 9.3% respectively of lifecycle all GHG emissions from transport in the EU. - Electricity produced 6500 MW, Heat 6700 MW Biogas 16000 MW 1,8 mln lit of gasoline	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Dry bread for feeding of swine and cattle
Type of project:	
Description of the project:	The approach is based on substitution of expensive wheat seeds by dry bread in feeding of swine and cattle by bakery wastes including: unsold bread, that do not meet visual standards to sell. Bread has a different nutritional value. Whole-grain baked bread has a value similar to wheat or rye. White bread contains less fiber and more starch. The mold on the bread is unacceptable, as well as additives such as cold meats, which may come from sandwiches. There are no barriers for wide spreading this approach. Nevertheless, there is a problem with specialised mills for these purposes on the market. In practice farmers use mills designed for other purposes can work in a very efficient way.
Location:	N/A
Timing:	N/A
Global budget invested in the pilot:	Costs include following items: costs of bread (low costs), cost of transport and energy needed for grinding of wasted bread, cost of mill.
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Fodder for animals – liquid material.
Type of project:	Recycling of bakery wastes in the agricultural sector.
Description of the project:	The approach is based on substitution of expensive wheat seeds in feeding of swine by mixture based on different substrates, including bakery wastes: unsold bread, buns, hot dog and hamburger buns, cracked, blown products that do not meet visual standards to sell. We can distinguish three basic types of bakery waste: - Polish bread, Polish breads and rolls, produced on the basis of wheat flour, rye flour, etc., - American bread, these are all kinds of rolls produced for fast food, i.e. hamburger buns and hot dog type, - mixed bread, or Polish bread together with American bread.

	According to the nutritionists, the best variant is mixed bread: the dry mass is quite diverse and constitutes 70-80% in the product. The protein value varies between 12-13% and 15-17 MJ digestible energy. Bread content in the fodder mass is usually up to 10% mixed with other material. The mixture can contain: whey, maize, beer yeast, a distillery from nearby breweries, bread from bakeries, rapeseed cake, beet and potato pulp, wastes from cleaning of yogurt technological lines. Additionally: cereals, soybean, complementary feed complemented individually. Good practice on bigger farms today is to operate two tanks of smaller volume. One is employed in preparing the next meal while the first is going through a feeding cycle. The system consists of: high pressure tank cleaner, mixing tank, storage tanks, feeding pumps, centrifugal pumps, feeding valves, main valves, pipes. Liquid feeding allows also for initial fermenting of the material which is beneficial for the health of the animals. Investment cost is 30 – 50 thousand Euro per 1000 pigs., tj. 30 - 50 Euro/pig (Polish prices). Savings feeding from 10-20 Euro/pig. For 3000 pigs 40 up to 60 thousand Euro of additional profit. Feeding Installation is required. Example: installation designed by TEWE company from Poland. It is the micro feeding system with back flushing of the installation from TEWE, which is not only a producer - designing of wet feeding systems. In the installation, after each feeding process, the pipes are rinsed from the rest of mixture. The water used for this purpose is not wasted because it is taken at the next feeding to prepare another food mix. The solution guarantees hygiene of feed. The pig house may need reconstruction. It is necessary to designate an appropriate place for the feeding kitchen, changing the layout and number of pens, introduction of sorting system. The importance of regular cleaning for both tank and pipe was emphasised by all suppliers at EuroTier. They explained a range of options for this task. Acids could be added to the tank several times daily, for example, with the opposite of an alkaline treatment being administered once per week. Pipelines may be washed through with the alkaline solution every 4-6 months. There is also chemical cleaning with proprietary sanitisers and the equipment systems on offer include the use of ultraviolet light (cheap, but lamps sometimes need cleaning) to kill bacteria in the tank. There are no barriers for wide spreading. Nevertheless the hygienic conditions must be provided. This approach requires a good feed base. There are some issues to be controlled: -Storage in dry, well-ventilated places in order to not allow mold to grow. -We can either preserve bakery waste with propionic acid, or simply use it as a fodder quickly. Un-preserved feed is suitable for consumption up to 7 days. The quality of the bread is also very important: the under-baked yeast can produce a large amount of gases at high temperature that may be dangerous for animals. Liquid feeding can increase effluent production (7.31 v 5.20 litres per pig/day)

	Transport over any significant distance for bulky liquid by-products is often a problem. Variable freshness and a lack of uniformity can also be important. Frequent sampling for a test of content and consistency is an essential part of the liquid feeding process. There is essential risk for the husbandry if the installation is not well maintained.
Location:	Polish examples: Pig farms from Wilczyce, Puławy etc. Poland
Timing:	This practice is already applied in Polish agriculture and Europe
Global budget invested in the pilot:	Cost of installation and reconstruction of pig house. The saving of 20 to 30 per metric ton are assumed for the liquid system. The largest discount over the cost of purchased complete feeds is being obtained by those closest to the major sources of wet by-products, with the most common examples coming from the brewing and bakery industries as well as from the industrial processing of milk and potatoes.
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Sonextra Sustain
Type of project:	Return bread from supermarkets and off-specification bread from bakeries used as bread ingredient after controlled fermentation. This is a recycle
Description of the project:	Return bread is fermented in a food safe way with a starter Sonextra Sustain®. Sonextra Sustain® is a unique starter that can efficiently generate sour dough from wheat bread, thus enabling the process of re-using old bread or out-of-spec bread. Sonextra Sustain is able to close the production cycle in a sustainable manner, as bread will not be downgraded from high quality food to feed or waste. This product gives bread extra flavour, less yeast required. Using this starter rope formation is prevented. The fermented bread can be used up to 20% in a normal bread recipe. Depending on the scale Fermentation equipment (up to 3 tons) to normal bakery equipment is required Feasibility for one industrial bakery and 100 retail shops is ca 200 k€; implementation in bakeries to use own out of spec bread has an ROI in 17 months or less (if existing equipment is used) Barriers for collecting return bread in a food safe way; new process in bakeries that lack expertise; allergens and seeds prevent ca 2/3 to be used in recycling, but other applications (saccharified bread for cookies/biscuits, application in honey cake or dairy/bread porridge seem to be feasible in pilot scale trials)

Location:	Netherlands
Timing:	Various projects 2009-2016
Global budget invested in the pilot:	N/A
Agents involved:	Wageningen University, industrial and artisanal bakeries, retailer, European Bakery Innovation Centre
Main results achieved: 30% of bread is wasted across the value chain; with this project 10-15% of this could be recycled	
Interesting links:	Filippos K. Zisopoulos, Sanne N. Moejes, Francisco J. Rossier-Miranda, Atze Janvan der Goot, Remko M. Boom, 2015. Exergetic comparison of food waste valorization in industrial bread production. Energy Volume 82, Pages 640-649

I.5. Vegetables:

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	Courtauld Commitment 2025
Type of project:	Supply chain action
Description of the project:	Ambitious voluntary agreement bringing together organisations across the food system to make food & drink production and consumption more sustainable. At its heart is a ten-year commitment to identify priorities, develop solutions and implement changes to cut the carbon, water and waste associated with food & drink by at least one-fifth in 10 years. Signed up to by many large companies, including Aldi, Arla, Asda, Dairy Crest, KFC, M&S, Nestle, Sainsbury's and Tesco Commitment and implementation by businesses – it is a voluntary commitment. Will also need to be financially sustainable for the businesses implementing it.
Location:	UK
Timing:	Current to 2025
Global budget invested in the pilot:	Investments offset by cost savings in individual businesses
Agents involved:	Retailers, manufacturers, agriculture, food service sectors
Main results achieved: It is expected to reduce waste and CO_2 emissions by 20% in 2025.	
Interesting links:	http://www.wrap.org.uk/food-drink/business-food-waste/courtauld-2025

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	Vegware
Type of project:	Compostable packaging and food waste composting
Description of the project:	Vegware is a UK company selling food packaging made from plant-based materials, designed to be fully compostable. The company has also trialled closed loop systems with clients that combine composting of food waste and packaging, in order to make compost for use in gardens.

	The company does an eco-audit of its own production processes and its claims in 2018 are: • 4,222 tonnes of CO2 saved • 1,400 tonnes of virgin materials saved • 3,226 tonnes of finite materials diverted It has a full range of disposable packaging that food businesses might use, from cups and plates to cutlery and takeaway boxes.
Location:	UK
Timing:	Current
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: CO_2 savings (tCO_2): 4,222 Waste reduction (t): 3,226	
Interesting links:	https://www.vegware.com/eco-audits/info_57.html https://www.vegware.com/close-the-loop/info_50.html

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Rubies in the Rubble
Type of project:	Use of waste food to create new human food products
Description of the project:	Using produce discarded from fruit and vegetable markets in London, Rubies in the Rubble create products such as relishes, ketchups and sauces from this 'waste'. The fruit and veg 'rescued' from markets and other outlets would otherwise have gone to landfill waste sites, so the company diverts waste and turns it in to human food products.
Location:	London, UK
Timing:	Started in 2011
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: 202 tonnes CO2e saved, 4.3 million pieces of fruit and veg saved	
Interesting links:	https://rubiesintherubble.com/

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Wonky veg
Type of project:	Sales of outgraded vegetables
Description of the project:	ASDA is a major UK supermarket chain, and in order to address the wastage of out graded vegetables it set up 'Wonky veg'. This is a box of out graded vegetables, sold at about £3.50, considerably below normal retail prices. Out grade veg includes that which is misshapen, 'wrong' sized or in some other way falls outside of grading requirements, but is otherwise perfectly edible. Since 2016 the scheme has diverted around 600 tonnes of good vegetables from landfill, animal feed or composting to human consumption.
Location:	UK
Timing:	Current
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: Waste reduction (t): 600	
Interesting links:	https://corporate.asda.com/newsroom/2017/01/20/asda-wins-at-wonky-veg

I.6. Cross to all:

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	ECO SHOP
Type of project:	Collection of all kinds of residues: Paper/cardboard, plastics, glass, tonner, oils, batteries, clothing, light bulbs, wood, contaminated packaging, rubble and small electronic devices.
Description of the project:	Eco Shop is a loyalty free card, delivered to the citizens as a method to recognize their collaboration in the recycling process. The recognition is based in the accumulation of points on card, which can be later exchanged for goods or services, listed in a catalogue. Points can be gathered through voluntary surrender of waste, in currently four drop-off sites (two sites at the beginning of the initiative). This initiative was launched in 2013 and obtained a growth mainly from domestic flow in cardboard (14%), plastic (9%), glass (75%), in batteries (24%) and used cooking oils (74%). Is still growing with 194 new customers in the first semester of 2017. Point associate with the kind of waste are associated based in its value and importance for the recycling process. The product and services offered include, for example, recycling containers, eco-bags, visit to the recycling unit, training packs and discounts on services and products like restaurants, coffees, cleaning services, etc. Drops-off points and a computer software that is responsible for managing the users' registration, material inputs and managing customer points. The data are recorded, using the support software, managed by a computer with barcode scanner that associates the points' card to the user.
Location:	Two cities in Oporto region, Valongo and Gondomar.
Timing:	Began in November 2013
Global budget invested in the pilot:	Eco Shop required an initial investment about 19000€ for informatics equipment, communication campaign and for management software. The functioning of the project has a residual cost linked to the goods and services awarded to the citizens.
Agents involved:	Promoter (LIPOR - Waste Management Organisation) Main Sponsor (Socieda de Ponto Verde – take back and recycling of packaging waste in Portugal) Stakeholder (Gondomar Municipality- drop od site managing body)
Main results achieved: Growth mainly from domestic flow in cardboard (14%), plastic (9%), glass (75%), in batteries (24%) and used cooking oils (74%).	
Interesting links:	http://www.regions4recycling.eu/upload/public/Good-Practices/GP_Lipor_Eco-Shop.pdf

	https://www.lipor.pt/pt/servicos/cartoes-de-fidelizacao/eco-shop-parque-aventura/destaques/clientes-ecoshop-continuam-a-aumentar-em-2017/

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Borough Market, UK
Type of project:	Waste food diversion
Description of the project:	An ancient and iconic food market in London that sells a huge rand of produce of many cuisines from around the world. Many market stalls have surplus produce every day and the Market wanted to reduce its waste. It now offers surplus food to several local charities, including those working in the areas of mental health, supporting the disadvantaged and homeless.
Location:	London, UK
Timing:	Current
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: Last year it diverted 15.6 tonnes of food waste from landfill.	
Interesting links:	http://www.foodsave.org/wp-content/uploads/2015/06/boroughmarket.pdf

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Feeding the 5,000
Type of project:	Food waste campaign
Description of the project:	Feeding the 5,000 is a campaigning event to shine a light on the global food waste scandal, champion the delicious solutions and catalyse the global movement. At each event, we serve up a delicious communal feast for 5,000 people made entirely out of food that would otherwise have been wasted. We bring together a coalition of organisations that offer the solutions to food waste, raising the issue up the political agenda and inspiring new local initiatives. There is also a Food Waste Pyramid to support businesses in reducing food waste. This offers principles, ideas and contacts to enable businesses to

	reduce their food waste. The Pledge has been signed by many major food businesses.
Location:	UK
Timing:	Current
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	https://feedbackglobal.org/get-involved/are-you-a-business/ https://feedbackglobal.org/campaigns/feeding-the-5000/

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	WRAP – food packaging guidelines
Type of project:	Food labelling
Description of the project:	A lot of food is wasted in the home and at retail because of labelling issues. Either food is not stored correctly (e.g. not refrigerated when it should be) or is thrown out due to excessively short 'use by' dates. Changes in guidelines to retailers and manufacturers by UK-based WRAP programme have created a positive impact on food nationally. The results from 2015 to 2018 show a reduction of 150,000 tonnes of food wasted across the UK. This includes changes to refrigeration and freezing advice, as well as alterations to 'best before' and 'use by' advice.
Location:	UK
Timing:	Current
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved Waste reduction (t): 150,000	
Interesting links:	https://www.lovefoodhatewaste.com/article/introducing-you-little-blue-fridge-and-snowflake-icons-food

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	New Covent Garden Market, UK
Type of project:	Waste food diversion
Description of the project:	The first UK market to install a materials recycling facility and pay as you throw scheme which enabled it to send food not fit for human consumption to livestock feed and achieve zero waste to landfill. The UK's largest fresh produce market, New Covent Garden Market situated in Vauxhall, has completely revised its waste system. A pay as you throw scheme has now been permanently launched following a trial in 2009, which allows for the food waste to be separated and sent away to be used as livestock feed or compost. Its resident food traders now have their own bins for organic, recyclable and general waste fitted with microchips. The bin is collected and weighed up and a ticket is printed out and stuck on the side of the bin detailing the weight and type of waste. Before the new system was installed, tenants paid a standard rate for waste collection according to the let area of their unit. Under the new system, tenants are now charged for organic waste around half the rate of what general waste collection costs them. This brings significant savings to businesses and acts as a financial incentive for them to separate their food waste from other materials. Instead of sending around 1000 tonnes of waste to landfill each month, the market has now achieved its target of zero waste to landfill. A real benefit is that being charged for what you waste has altered behaviour and traders have adopted practices to minimise waste at source and so reduce volumes. It has enabled them to quantify the consequences of their actions in financial terms. Food that businesses cannot sell and is unfit for human consumption, such as vegetable peelings and out of date fruit and veg, is sent to a pig farmer in Oxfordshire for livestock feed. This provides a much cheaper alternative to imported grain feed for the farmer as well as a varied diet for the pigs. It also gives the farmer a competitive edge, as he now has a delicious meat product with better environmental credentials.
Location:	London, UK
Timing:	Current
Global budget invested in the pilot:	N/A
Agents involved:	N/A

Main results achieved: Waste reduction (t): 1.000	
Interesting links:	N/A

Inventory of Successful Approaches to food waste reuse and recycling

General Information	
Project title:	Poco Tapas Bar
Type of project:	Reduced food waste and recycling
Description of the project:	Poco is a tapas bar based in Bristol and London, UK. Its method is about serving ethical food (local, seasonal, organic) and this extends right through to waste as well. The first approach is about reducing wastage in the first place: • Ingredients are ordered daily and dishes allowed to run out in order to keep food fresh and avoid an excess of produce. • Recipes have built in rescue-recipes that turn surplus or bi-products into delicious dishes e.g. If less mackerel is sold than expected, the chefs will notice the excess in good time and make an escabeche. • If any wastage occurs in the kitchen it is recorded in a table with a column for reasons and actions to stop it happening again. This table is now almost always completely empty. • If plate waste is returned from the tables frequently the specific dishes or elements of the dish are recorded and communicated to the chefs. e.g. removed flatbread from the squid dish as many people weren't eating it. The next stage is how to effectively recycle food and other waste: • 95% to 100% of waste is composted and recycled • Based on the principles of a circular economy, all the products are chosen so they can be re-used circulating at a high quality or renter the biosphere safely, either by being eaten or composted or renewed safely. • The chefs and waiters weigh our bin bags each day, keeping a record of what and how much we are wasting so that we can analyse and reduce it in the future. • Products are ordered with little to no packaging; if a product isn't available from any local supplier without packaging, it will only be purchased if the packaging is recyclable. If a supplier brings a product with non-recyclable packaging the supplier may be asked to take it away and re-use it. e.g. polystyrene fish boxes. • A cooperative has been formed with local restaurants in Bristol for our waste scheme in order to compost and recycle all of the waste.

Location:	London and Bristol, UK
Timing:	Current
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: At least 95% of food waste recycled	
Interesting links:	http://pocotapasbar.com/about/ethics/

I.7. Others:

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	Reusing of fish processing wastes in feeding and other related purposes
Type of project:	Recycling/reuse
Description of the project:	Fish waste processing plant, which enables production of good quality fish meal of protein digestibility coefficient of 95%. During the process modern technologies are applied including system of deodorization of smells as well as unique non-sewage production technology. Operator keeping technological cooperation with scientific and research units (technical universities, Sea Fisheries Institute in Gdynia). Fish processing remains are turned on fish meals, fish oil, fish feed, baits for fish, fishing ground bait, food for dogs and cats, extrudates for mink and foxes and other extrudates, new generation fodders for young animals (piglets and chickens) on the basis of fish broth. All under implemented HACCP system and obtained integrated environmental permit. http://en.agro-fish.pl/
Location:	Kartoszyno, 2 Żarnowiecka street 84-110 Krokowa, Poland
Timing:	SME established at 2000 year
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	N/A

	Inventory of Successful Approaches to food waste reuse and recycling
General Information	
Project title:	Co-fermentation of sewage sludge and deposits from fish production, meat processing and food waste
Type of project:	Organic waste recycling by turning into biogas and fertilizer. Sector: fish production, meat processing and food waste

Description of the project:	Combined co-fermentation of sewage sludge and deposits from fish production, meat processing and food waste is the technology provided by WARTEC. The use of listed organic waste within the process of sewage sludge fermentation improves the achieved results: the organic dry matter reduction, biogas production and thus also the production of electricity and heat increase. During process the pasteurisation parameters provide in-depth reduction of pathogens (PFRP) class A (according to EPA terminology). In the case of hygienization of only sewage sludge, a temperature of 70 ° C is required for a period of 60 minutes. This enables the processing of also zoonotic waste in the installation (Category 3 material), eg. from the meat, dairy and fish industries. The final products of the biochemical decomposition of organic substances under anaerobic conditions is biogas, containing 60-65% of methane - a valuable energy source and digestate that can be used as an organic fertilizer. The post-fermentation residue, due to previous hydrolysis / pasteurization, is completely free from pathogens and can be used as a fertilizer without any additional action. WATREC technology makes it possible to obtain digestate with a dry matter content of approx. 4-5% and in this form it can be used as a liquid organic fertilizer with a high content of phosphorus and nitrogen to the increasingly popular soil injection in agriculture. The technological process uses deodorization systems from various devices such as biochemical washes and active carbon filters.
Location:	N/A
Timing:	N/A
Global budget invested in the pilot:	N/A
Agents involved:	N/A
Main results achieved: N/A	
Interesting links:	http://www.watrec.com/pl/rozwiazania/zagospodarowanie-osadow-sciekowych/

Annex II. Success cases and innovation

II. A. Bioplastics

II. A1. Success case: VTT Technical Research Centre of Finland[20]

The **VTT Technical Research Centre of Finland** has created a compostable multi-layer material from agricultural and forestry by-products. The VTT material solution looks like plastic and performs like plastic, but comes from wood. It can also be made from fast-growing plants like rice straw and sugar cane tops, recycled fibres, textile waste and agricultural residues. Cellulose is inherently safe, renewable, recyclable and biodegradable.

VTT's material is well-suited for many food packaging applications. These include: snack bags and stand-up pouches for dry goods such as cereal and nuts; a flexible packaging for air-sensitive products like chocolate, biscuits, and thin cuts of meat or cheese; and potentially some liquids and moist food.

It is entirely bio based and compostable and it has the potential to diminish the use of fossil-based materials, reduce the pollution of waterways by microplastics and mitigate food losses.

II. A2. Success case: Full Cycle PHA[21]

Full Cycle PHA is naturally produced by a bacteria using mixed organic waste as raw material. It can replace a wide range of synthetic plastics, yet it is compostable and marine degradable once its useful life is over. It is also cost-competitive with fossil-fuel based alternatives, creating the potential for widespread adoption and scale in both developed and emerging markets.

Its mains characteristics are: **1:1 price-competitive** with traditional, synthetic oil-based plastics, uses **organic waste as raw material**, which is readily available and low cost, it is also **food-contact safe, and** after use, organic PHA becomes raw material that can be **upcycled again into virgin PHA.**

Despite its easy and quick biodegradation, packages made with this material can be kept for years in a clean and stable environment**, for example, store shelfs.**

Full Cycle Bioplastics says that food waste, agricultural residues, green waste and also dirty and unrecyclable cellulosic material, such as paper or cardboard, can be converted into PHA.

II. A3. From plants to ecological plastic: PLA[22]

PLA (Polylactic Acid) can also be obtained from plants, such as corn or sugar cane, transforming starch into polymer, obtaining PLA granulate, and then producing this ecological packaging. PLA production reduces CO_2 emissions up to 62%.

II. A4. From the ground to the table: CPLA[23]

[20] https://newplasticseconomy.org/innovation-prize/winners/vtt-technical-research-centre-of-finland
[21] http://fullcyclebioplastics.com/
[22] https://www.ecoologic.com/de-las-plantas-al-bioplastico
[23] https://www.ecoologic.com/materiales-sostenibles

CPLA is a type of PLA with an additive that provides high temperatures resistance properties that pure PLA does not support. It emits the same low CO_2 emissions during its manufacture as PLA and is also compostable like the rest of ecological plastics but reinforced to resist temperatures up to 85°C. This material is used in articles that must resist heat such as lids for glasses and tubs for hot liquids and cutlery. CPLA-made packages can be used in conventional oven or microwave. They are discarded with the rest of the food waste in organic containers.

II. A5. Success case: Evoware, seaweed-based packaging[24]

Awarded by the Ellen McArthur Foundation, Evoware, an Indonesian company that produces this bioplastic, collaborates with local farmers to provide best quality seaweed. This bioplastic has very interesting qualities: it dissolves in warm water, is 100% biodegradable and works as natural fertilizer for plants, it has 2 years of shelf life, it is nutritious, contains high fibre, vitamins and minerals (it is eatable); can be customized to give specific taste or colour and it is printable and heat sealable. Companies from countries such as Sweden, Indonesia and France are producing this bioplastic.

But Evoware's products still have some way to go before they can compete with plastic on price. As well as the other Ellen McArthur Foundation Award winners, Evoware has participated in a yearlong accelerator program in 2018. An innovation process to be followed.

II. A6. Success case: Vegware[25]

Vegware is a manufacturer and visionary brand, globally specialized in plant-based compostable foodservice packaging. They offer a wide range of packaging products, all them plastic-free, made from paper and card, bagasse and PLA/CPLA,

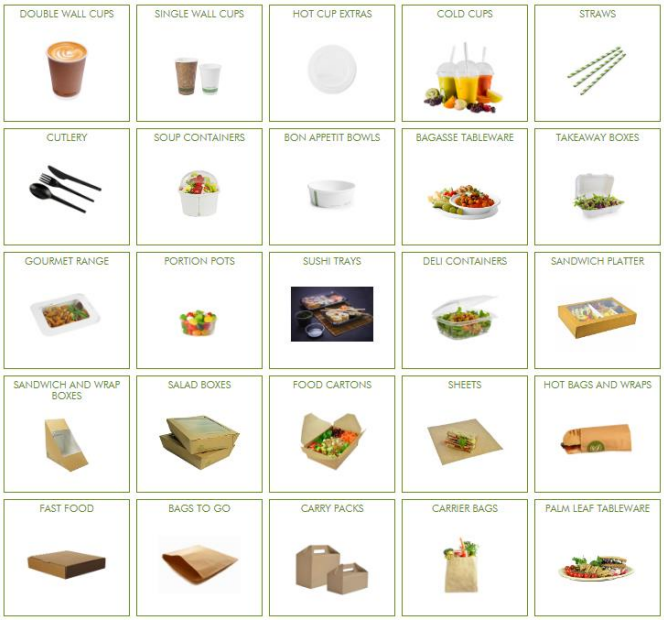


Figure 13. Vegware catalogue (source www.vegware.com)

II. A7. Success case: Bodega Matarromera[26]

[24] http://www.evoware.id//product/ebp

[25] https://www.vegware.com/

[26] https://www.aimplas.es/blog/envases-ecologicos-bodega-matarromera-desarrolla-la-primera-botella-de-vino-de-pla

Bodega Matarromera (Spanish wine producer) has successfully completed the development of a new sustainable packaging for its wines. It is a bioplastic container, specifically PLA, and is the first bottle made in this material that reproduces the design of traditional glass bottles for wine with the advantage of being much lighter, totally recyclable and with a lower environmental impact than its manufacturing process.

II. A8. Success case: Algae based bottle[27]

Ari Jónsson is an Icelandic designer aware of the problem posed by plastic bottles for our planet because, in most cases, these containers are for single use and take many years to disappear.

The agar is a gelatin that is obtained from different types of algae, widely used in the food industry. Its use is very frequent also, in laboratories, as a culture medium in microbiology and for the realization of electrophoresis gels (used to separate biomolecules by size) in molecular biology.

The bottles do not have a very careful aesthetic because they have been manufactured in a completely handmade, with 100% organic and natural materials, without processing and, although the water stored in them is drinkable, after a while, according to its designer, it catches some seaweed flavour. In fact, it is totally edible, although Jónsson does not assure that its flavour will satisfy consumers, because of that algae flavour.

II. B. Replacing multilayer plastics with monolayer plastic

II. B1. Success case: Aronax Technologies, identified and separable layers[28]

With this idea, Aronax Technologies Spain proposes to incorporate a magnetic additive for plastics. Because of the magnetic properties of the additive particles, they can make it easier to identify and separate the packaging at the recycling stage. In addition, thanks to their magnetism, the particles could potentially be recovered separately in the future, by melting or dissolving the packaging and retrieving a purified polymer, while collecting the particles to be used again. The additive – small, plate-like particles of silicates and iron oxide – will provide plastics with much better abilities to block gases such as oxygen and can be used in both recyclable and compostable plastics.

B2. Polyethylene and nanoengineering[29]

The **University of Pittsburgh** team applies nanoengineering to create a recyclable material that can replace complex multi-layered packaging that is unrecyclable. This mimics the way nature uses just a few molecular building blocks to create a huge variety of materials.

The idea is to make food packaging from layers of a single material, polyethylene, which is easy to recycle. Each layer can be given different properties by changing its nanoscale structure, which when combined, create a much better material that can even be coloured without pigments. It aims to replace packaging made from layers of different materials, which are growing in popularity today but are very difficult to recycle. Since this innovation aims at

[27] http://fluyecanarias.com/botella-biodegradable-ari-jonsson/

[28] https://newplasticseconomy.org/innovation-prize/winners/aronax-technologies-spain

[29] https://newplasticseconomy.org/innovation-prize/winners/university-of-pittsburgh

accomplishing the task currently done by combining materials like PET, polyethylene and aluminium, but using only one, recyclable material, it combines the best of two worlds.

The approach is to alter the nanostructure of polyethylene in ways that allows it to mimic the properties of the various layers (such as PET, EVOH, or even aluminium) in current laminate packaging while not changing the chemistry (it's still polyethylene). Therefore, when the material is collected, shredded, and melted, it reverts to simple molten polyethylene and can be reprocessed without difficult separation steps.

II. B3. Success case: RefuCoat, hybrid coating[30]

Hybrid bio-based high oxygen/water barrier and active coatings to be used in a monolayer bio-based food packages (films and trays) as alternative to current metallised and modified atmosphere (MAP) packages to avoid the use of non-renewable materials in multilayer structures that currently lead to complex and expensive recycling steps.

RefuCoat is a company that makes this type of coating. RefuCoat aims to develop a full recyclable monolayer bio-based barrier and active packages for food applications including cereals, meat, snacks and savoury products: "Hybrid coating formulations combine cost-efficiently produced polyglycolic acid (PGA) and modified silica oxide. Fully biodegradable packages for fresh food products are obtained with middle chain modified PHAs. PGA and PHA based hybrid coatings with high gas barrier properties will be further improved with active substances for improved shelf-life. Furthermore, new packages based on bio-PET and bio-PE combined with hybrid and active coatings will be developed."

All selected materials and additives fulfil the current legislation related to plastics for food-contact applications. For example, Regulation EC 10/2011 on plastics intended to come into contact with food and Regulation EC 450/2009 on active and intelligent materials and articles intended to come into contact with food. Bioplastics, however, generally have lower barrier to gas and moisture than oil-based plastics. This is not a problem, when bio packaging is used with fresh products such as fruits, vegetables and bread but it can be a problem for foods that require a longer shelf life such as fresh meat or fish; PHAs are a fully biodegradable biopolymer with the lower moisture permeability, a clear advantage in order to protect the hybrid coating from moisture.

II. C. Replace plastic with paper and cardboard

II. C1. Success case: Smurfit Kappa[31]

Said to be one of the most important packaging companies in the world, Smurfit Kappa is a company that offers natural, renewable and recyclable packaging solutions out of cardboard. They offer a wide range of food packages including transport package (from farm to manufacturers and from manufacturers to retailers), where security and protection is crucial, and storage package which might need an eye-catching look.

[30] https://www.refucoat.eu/the-science-behind/

[31] https://www.smurfitkappa.com/vHome/es/Products/Paginas/meat_Poultry_A_Fish.aspx

II. C2. Success case: Agua en Caja[32]

From the Castillo de Gormaz mineral spring, located in the province of Soria, Agua en Caja Mejor is presented in a container that contributes to the care of the environment by replacing the conventional container up to now: the plastic or glass bottle. The new packaging, made with biodegradable and renewable materials, means a significant reduction of the environmental impact.

II. D. Returnable packaging

II. D1. Bags

Bags play a huge role in plastic issue. Their light weight combined with its common single use make them the perfect candidate to become trash and to end up in the ocean.

Nowadays in many countries it is very common to see people carrying their own bags and/or trolleys when shopping food. That is a very positive trend, as it fosters reuse and lengthens a product's life cycle. However, not everybody does it, so supermarkets provide bags to the customers. If they implement our previously recommended bulk selling model, customers need bags or package for this bulk sale products and bags to carry their shopping home. Here, supermarkets can find a business opportunity and offer the chance to buy them in their stores. They can sell various types of bags and package such as: kraft paper bags, cotton bags, PLA/CPLA containers and compostable bags. These latter could also be brought back to the supermarket which may collect them and send them to compost plants thus providing their own raw materials to produce their future bags which will be sold in their stores. If customers do not return compostable bags they can use it as trash bags as they are a much better option than plastic bags as they can be thrown into the organic containers.

Figure 14. Greenhome compostable bags (source www.greenhome.com)

II. D2. Success case: Foodtopia, returnable packaging[33]

[32] http://www.expansion.com/fueradeserie/gastro/2017/03/01/58b540e3e5fdeabd7e8b45ed.html

[33] http://foodtopia.eu/

Foodtopia is a Spanish restaurants chain concerned about environmental and social issues.

Their business model consists of returnable packaging. They offer their day menu dishes each of them packaged in glass containers. The first time you go you pay an extra 1.5 euros fee for the container. Then, every time you go you can bring your container with you and leave it in return of a new dish without paying any extra fee.

Figure 15. Foodtopia returnable glass food containers