ASTER

THE BIOREFINING OPPORTUNITIES IN EMILIA-ROMAGNA

CENTRAL EUROPE
COOPERATING FOR SUCCESS.

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

plastice

Prepared for:
www.aster.it
by Dott. Luciano Vogli

in collaboration with:
CIRI Energia e Ambiente
Interdepartmental Industrial Research Center, Energy and Environment,
Biomass unit of the University of Bologna
Diego Marazza, Vittoria Bandini, Fabiola Farina, prof. Andrea Contin
Technopole of Ravenna

This publication is implemented trough the PLASTICE project
www.plastice.org, CENTRAL-EUROPE programme co-financed by the ERDF

THE BIOREFINING OPPORTUNITIES IN EMILIA-ROMAGNA

UNDERSTANDING THE POTENTIAL FOR BUILDING
A SUSTAINABLE BIO-BASED ECONOMY IN EMILIA-ROMAGNA,
USING BIOMASS AS A RENEWABLE SOURCEOF KEY COMMODITIES

ASTER
RETE ALTA TECNOLOGIA EMILIA-ROMAGNA HIGH TECHNOLOGY NETWORK
plastice
CENTRAL EUROPE
EUROPEAN UNION
CIRI ENERGIA E AMBIENTE
UNITÀ BIOMASSE

TABLE OF CONTENTS

1.
KEY FIGURES

This report was commissioned to enhance the existing biobased economy background in Emilia-Romagna and the forward opportunities. Biobased economy is achieved in this conception through the use of renewable, non-genetically modified, non-food crop based feedstocks.

This study concludes that:

- There is a large availability of biomass of various origins, not only from bioenergy crops. A conservative appraisal accounts for 20 Mtons of bulk residual biomass produced corresponding to 5 Mton of dry matter (DM). A large share of this production is suitable for bioenergy, biomaterials and added value products.
- This is a new and thriving sector; in Emilia-Romagna active and leading companies are operating in the biotechnological, agro-industrial and bioenergy sector. The revenue of the Green Economy sector in the region is estimated at 57 billions euro.
- New industrial alliances are binding together agri-food, chemical and biotechnological industry. The Novamont and Genomatica joint venture, the Novamont and Versalis one, and the one involving Orogel, SFIR and Biosphere are examples of respectively international, national and regional strategic alliances which track new ways of doing business in this sector.
- Emilia-Romagna has a strong relevant science and technology base that could underpin the development of the necessary supply chains. It's worth noting that not only public research is operating in this domain, but also many private labs are flanking chemical and agri-food industry.

2.
INTRODUCTION

2.1. WHAT IS BIOREFINING?

THE BIOREFINERY CONCEPT

The concept of Biorefinery is the heart of the IEA Bioenergy Task 42, and is defined as "the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, and chemicals) and energy (fuels, power, heat)". So a Biorefinery can be seen as a facility, a process that converts biomass into purified materials and molecules that result in usable bio-based products, such as chemicals, fuels and fibers, that are normally produced by fossil fuels. The Directive 2009/28/EC of 23 April 2009 defines 'biomass' as: "the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste". This means that biomass refers to a wide range of organic materials which can be used in the supply chain of biorefineries.

The biomass feedstocks consist of whole plant material derived either from dedicated crops or waste and by-products of agriculture and forestry, and that can be divided into lignin, hemicellulose, cellulose and starch through various processing techniques. A particular category of biomass is agricultural biomass. Agricultural biomass role in the bio-economy involves producing biomass feedstock - mainly crops, grasses, trees, crop and livestock wastes - that are converted through a range of processes - for example fermentation, gasification, and combustion - to produce: fuels (such as ethanol, renewable diesel, hydrogen), power, electricity, heat, and a wide range of chemical and fibre-based products (e.g. plastics, adhesives, paints, detergents, pharmaceutical and healthcare products, cotton, and linen).

Bioenergy from agricultural biomass is derived from two main sources, agricultural crops and agricultural waste products. Energy production from agricultural crops can be divided into two main groups, liquid and solid energy forms. Liquid energy covers energy sources such as ethanol burned in engines, usually derived from annually harvested agricultural crops such as sugar, wheat, maize and rapeseed. Solid energy covers energy sources for power generation through electricity and heat, usually produced from agro-forestry products such as poplar and willow, and grass production, for example, elephant grass. Energy production from agricultural wastes includes wastes from both plants (e.g. straw) and livestock wastes (e.g. manure, slurry), which are mainly converted to produce heat and electrical power.

Biomaterials are renewable raw materials which cover the following main groups:

- Industrial oils derived from oilseed crops, such as rapeseed and sunflowerseed, and used to manufacture lubricants, surfactants, printing inks, paints, coatings and fragrances;
- Starch and sugar from cereals, potatoes, sugarbeet and cane, used to produce pharmaceuticals, cosmetics, detergents, paper, and healthcare products;
- Fibres mostly from fibre crops, such as hemp, flax, cotton, and miscanthus, used to manufacture textiles, paper and panel products, and in combination with synthetic fibres in fibre composites;
- High-value, low-volume products derived from a large variety of plant species, used in pharmaceuticals and healthcare products, crop protection and food preservation products, and flavours and fragrances.

A generic biorefinery is shown schematically in Figure 1.

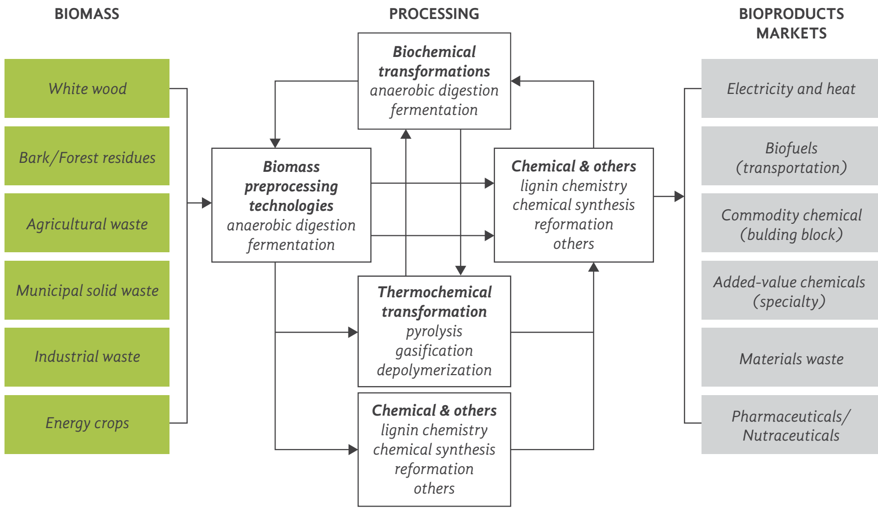

Figure 1. Biorefinery feedstocks (upstream side), conversion technologies and product markets (downstream side). Source: Systems Perspectives on Biorefineries, 2013.

As said earlier, the transformation of biomass feedstocks integrated with the production of secondary energy in a biorefinery can be seen as the processing of crude oil in a refinery, with the exception that in the first case, for effective management of the complex flows of materials and energy, it is essential to use any element of the starting material, maximize energy savings and reduce processing costs.

The international petrochemical production of chemicals and polymers are estimated at about 330 Mtons worldwide. The primary production is dominated by a small number of basic elements, in particular: methanol, ethylene, propylene, butadiene, benzene, toluene and xylene. These elements are mainly converted to polymers and plastics, but they are also converted to various fine chemical products with specific functions and attributes. From a technical point of view, almost all industrial materials made from fossil fuels could be replaced by their counterparts in biological basis. However the production cost of bio-based materials in many cases exceeds the cost of petrochemical production.

THE ROADMAP OF THE EUROPEAN COMMISSION FOR MOVING TO A COMPETITIVE LOW-CARBON ECONOMY IN 2050

With its Roadmap for moving to a competitive low-carbon economy in 2050, the European Commission has looked beyond short-term objectives and set out a cost-effective pathway for achieving much deeper emission cuts by the middle of the century. All major economies will need to make deep emission reductions if global warming is to be held below 2°C compared to average temperatures in pre-industrial times. The Roadmap is one of the long-term policy plans put forward under the Resource Efficient Europe flagship initiative intended to put the EU on course to using resources in a sustainable way.

The Roadmap suggests that, by 2050, the EU should cut its emissions to 80% below 1990 levels through domestic reductions alone. It sets out milestones which form a cost-effective pathway to this goal - reductions on the order of 40% by 2030 and of 60% by 2040. It also shows how those sectors mainly responsibles for Europe's emissions - power generation, industry, transport, buildings and construction, as well as agriculture - can make the transition to a low-carbon economy in the most cost-effective way.

In such a scenario, depicting a low-carbon society, we will live and work in low-energy, low emission buildings with intelligent heating and cooling systems, we will drive electric and hybrid cars and live in cleaner cities with less air pollution and better public transport. Many of these technologies already exist today, but they need to be further developed. Besides cutting the vast majority of its emissions, Europe could also reduce its use of key resources like oil and gas, raw materials, land and water.

The transition to a low-carbon society would boost Europe's economy thanks to increased innovation and investment in clean technologies and low - or zero - carbon energy. A low-carbon economy would have a much greater need for renewable sources of energy, energy-efficient building materials, hybrid and electric cars, 'smart grid' equipment, low carbon power generation and carbon capture and storage technologies. To make the transition the EU would need to invest an additional 270 billion euro or 1.5% of its GDP annually, on average, over the next four decades. The extra investment would take Europe back to investment levels seen before the economic crisis, and would spur growth within a wide range of manufacturing sectors and environmental services. Up to 1.5 million additional jobs could be created by 2020 if governments used revenues from CO_2 taxes and from auctioning of emission allowances to reduce labour costs.

2.2. DRIVERS FOR BIOREFINERY

The recent rise in oil prices, consumer demand for environmentally friendly products, population growth and limited supplies of non-renewable resources, have opened new windows of opportunity for bio-based chemicals and polymers.

Emerging economies require increasing amounts of oil and other products derived from fossil fuels, and this is leading to a more competitive market. In addition, security of supply is an important driver for bio-based products and bio-energy.

All over the world small steps have been taken to sway from an economy based on fossil fuels an switch to a more sustainable one, called bio-economy. The term "bio-economy" is derived from an economic theory proposed by Nicholas Georgescu–Roegen for ecologically and socially sustainable economy. Any economic process that produces material goods diminishes the availability of energy in the future and therefore the future possibility of producing other goods and material things. In addition, in the economic process matter is degraded, so less reliance can be put in future economic activity. Raw materials concentrated in underground deposits, once released in the environment can be collated and reused in the economic cycle only in a much smaller quantity and with a high expenditure of energy. Matter and energy, therefore, enter into the economic process with a relatively low degree of entropy and come out with a higher entropy. Hence the need to radically rethink economy, making it capable of incorporating the principle of entropy and global ecological constraints.

The transition to a bio-based economy has multiple drivers:

- an over dependency of many countries on fossil fuel imports;
- the anticipation that oil, gas, coal and phosphorus will reach peak production in the next future;
- the need for countries to diversify their energy sources;
- the global issue of climate change and the need to reduce the emission of greenhouse gases;
- finally, the need to stimulate regional and rural development.

The uses of chemicals from renewable sources show savings of GHG throughout their life cycle when compared to the equivalent conventional petrochemical sources. Emissions of CO_2 during the production and consumption of bio-based products are offset by the CO_2

captured during the growth of biomass used to produce them. The potential for reducing greenhouse gas emissions from the set up of second-generation biorefineries, compared to petrochemical sources, varies between 30% and 85%. In Europe, the adoption of biorefinery is seen as a key technology able to put into effect the effort to mitigate climate change and ensure security of supply against fluctuations in crude oil prices.

Biorefining offers support for rural development by providing additional market opportunities for farmers; moreover, decentralized production systems can provide new sources of income and employment opportunities in rural areas. Much of the agro-industrial waste is still a cost to the industry, due to the cost of disposal. In parallel to this situation, that we can consider inefficient, the market for bio-based bioplastics is experiencing exceptional growth in Europe and worldwide, as assessed on the basis of data of the European Bioplastic Association. These high value-added materials have considerable importance from the industrial and economic point of view, and their exploitation is a key step in the development of an economy based on exploitation and recycling of renewable resources: the Biobased economy or simply bioeconomy.

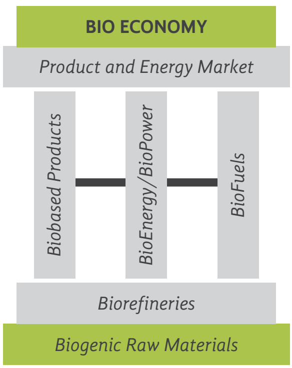

Figure 2. The 3 pillars of the biobased economy. Source: Kamm, 2008.

This trend towards a bioeconomy is emerging around the world as noted by Frost & Sullivan in a survey commissioned by Aster in 2011. Once defined the global context, it should be noted that particularly in Emilia-Romagna operate important enterprises connected to a significant production of agro-industrial waste type, as well as several developers of technologies for the exploitation of biomass. Due to the fact that these secondary raw materials are produced on large areas, bio-based production favors a decentralized structure. Equipment for biomass processing at regional level can bring benefits to local economy as well as a simplification of logistics and contractual situation, and lower capital requirements as opposed to a large central biorefinery. The regional structure separates raw biomass from fibres, animal feed and, potentially, high value organic compounds obtained from niche crops. The sugar components of biomass can then be separated and concentrated to provide the central biorefinery while the protein fraction can be recovered and used as high quality animal food.

Another main driver for the development and implementation of biorefinery processes is the transportation sector. Significant amounts of renewable fuels are necessary in the short and mid term to meet policy regulations both inside and outside Europe. Biofuels have to fill in a large fraction of this demand, specifically for heavy duty road transport and in the aviation sector where biofuels are the only reasonable alternative. Both conventional (ethanol, biodiesel) and advanced biofuels (lignocellulosic methanol, ethanol, butanol, Fischer-Tropsch-diesel/kerosene) generally cannot be produced in a profitable way at current crude oil prices. This implicates that they only can enter the market if they are forced to by governmental regulation, or if significant financial support is provided (i.e. tax reduction). This artificial market will not be a long lasting one: a significant reduction in biofuel production costs is required to create a sustainable market. A very promising approach to reduce biofuel production costs is to use so called biofuel-driven biorefineries for the co-production of both value-added products (chemicals, materials, food, feed) and biofuels from biomass resources in a very efficient integrated approach.

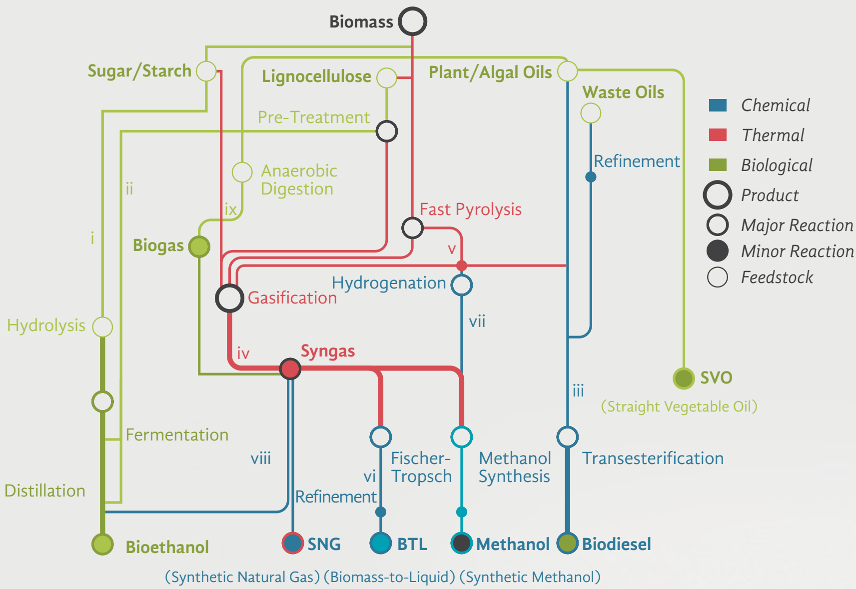

Figure 3. The multiple synthetic conversion routes of major biofuels produced from first and second-generation biomass feedstock. Source: WEC, 2010.

To be a viable option, however, the production of bio-based energy, materials, chemicals and biofuels, should be able to improve the global economy and, in some cases, it also could be a major source of income. In this perspective, the main driver for the creation of biorefineries is the answer to the "sustainability" issue. The development of biorefineries must be designed in a way that is sustainable from both environmental, social and economical point of view.

This new industrial development, if properly put into practice, will foster direct and indirect employment, creation of new professional figures and a better quality of life. Not to be overlooked, biorefineries will still have to be combined with existing infrastructures and, from both ethical and environmental point of view, many considerations must be made as regards the source of biomass in terms of competition for food, impact on consumption and on quality of water, changes in land use, carbon stocks in the long term, net balance of GHG and impact on biodiversity. Furthermore, the amount and type of energy used to operate inputs and outputs of the biorefinery and its related transport should be carefully considered.

2.3. BIOREFINERY TYPES

Biorefineries can be classified on the basis of a series of features. The main raw materials are perennial grasses, starch crops (e.g. wheat and maize), sugar crops, lignocellulosic primary biomass, lignocellulosic residues, oil, algae, and organic residues. These materials can be processed into biorefineries to get "platforms" of single molecules of carbon, or biogas and syngas, carbohydrates, starch, sucrose, cellulose, hemicellulose, lignin, oils (made from plants or algae), organic herbal solutions, liquid from pyrolysis. These primary platforms can be converted into a wide range of marketable products using combinations of thermal, chemical and biological processes.

In theory, biomass can be subjected to four different types of conversion processes:

- physical conversion, such as mechanical pressing;
- biological conversion: fermentation and anaerobic digestion;
- thermochemical conversion: incineration, gasification and pyrolysis;
- chemical treatment: extraction and chemical synthesis.

In the context of biorefineries we will focus on fermentation (biological conversion), gasification and pyrolysis (thermochemical conversion). Both types require energy conversion, which is produced by the processing of biomass and by the heat recovery site.

FERMENTATION

The fermentation processes are well understood and are currently used in the so-called first generation systems for the production of bio-ethanol from sugars and starches. The process can be adopted for the production of other "platform" chemicals or simple molecules that can serve as elements for synthesizing other chemical compounds. Evolution of second generation fermentation processes can produce a similar range of platform chemicals through the transformation of sugars, cellulose and lignin.

These technologies are still in a development phase (in particular in the United States) and because of the use of the whole plant, they require additional stages to first break down the plant's structural materials into fermentable sugars by using microorganisms or chemical treatment. These processes improve the range of usable raw materials and increase the proportion of raw material actually converted into useful products.

Second-generation technologies can offer higher yields per hectare of raw material compared to first generation techniques currently in use. Both processes produce solid residues with a high content of protein. These can be sold as animal feed or burnt to meet the high needs of power of the fermentation process. Fermentation processes have the potential to produce a wide range of different chemicals: compounds such as ethanol, succinic acid, lactic acid, citric acid, 1,3-propanediol, lysine and glutamic acid are already being produced through fermentation processes on a commercial scale within established markets as fuel, nutraceuticals and personal care cosmetic ingredients, elastomers, polymers and adhesives, and surfactants.

THERMOCHEMICAL

Thermochemical processes are very different from fermentation ones, as here heat is used to break down biomass chemical bonds. The products of thermochemical conversion differ depending on the type of process implemented.

Gasification, which operates at temperatures between 700°C and 1000°C, in shortage of oxygen, converts biomass into a gaseous mixture, known as 'syngas', containing: H_2, CO, CO_2, CH_4 and hydrocarbons. The syngas can be burned directly in internal combustion engines, or used to produce methanol, or hydrogen, or converted via the Fischer-Tropsch process into synthetic fuel.

Originally patented in 1935, the Fischer-Tropsch (FT) synthesis process has been commercially implemented for some time and can be used to produce biofuels. The process consists of feeding pure syngas, at controlled pressure and temperature, over a catalyst that assists in the formation of the desired hydrocarbon molecules. Catalysts, typically composed of iron, cobalt, nickel or ruthenium, are selected according to the desired fuel molecule.

Pyrolysis (or thermal cracking), unlike gasification, operates at lower temperatures (300-700 °C) and in total absence of oxygen. Such conditions of temperature and anaerobiosis, cause the break of chemical bonds giving rise to gaseous products (syngas), liquid (bio-oil) and solid (biochar), in proportions that depend on the applied method of pyrolysis (fast, slow, or conventional pyrolysis) and on reaction parameters (temperature, pression and residential time). The main high value compounds which are foreseen are phenols, organic acids, furfural, and levoglucosan.

The major advantage of a pyrolysis biorefinery is the possibility of decentralized production of bio-oil in regions where abundant biomass is readily available, making it possible to keep the minerals within the country of origin and creating the premise of cost-effective transport of resulting liquids. The basis for creating high value compounds is the cost-effective fractionation of the pyrolysis oil. Fractionation will result in various qualities of oil which can be transformed, though further upgrading, into fine chemicals, petrochemicals, automotive fuels and energy.

3.
THE BIOREFINERY SUPPLY CHAIN

Biomass is bulky and heterogeneous if compared to liquid hydrocarbons from fossil sources. Pre-treatment located in farms with in-place processing is necessary for the logistics and economics of the overall biorefining process. The presence of a deep-water port, of road and rail links as well as storage infrastructures located nearby is important for the economic management of raw materials.

Each stage of the supply chain have particular technical difficulties that require an interdisciplinary approach. There are also concerns associated with economic, social and environmental issues at each phase.

Figure 4. The generic representation of a biorefinery supply chain: UPSTREAM the feedstock biomass; CONVERSION processes; DOWNSTREAM market products.

3.1. UPSTREAM

FEEDSTOCK

Experience in the development of innovative crops and in better fitting for processing conditions, or in maximizing the desired components is important for improving the efficiency of a biorefinery. The cultivation and harvesting of raw materials can affect the composition and therefore basic agricultural expertise is important. The raw material and the supply chain problems in the fields of competition for the land, competition between food and fuel, biodiversity conservation and use of scarce water resources are dominating the public debate.

TRANSPORT

The pre-treatment of raw materials can facilitate logistics and transport, as well as the generation of new employment opportunities. Increased traffic of goods in rural areas can affect the environment and can be unpopular with the general public. A cost-benefit analysis must be carefully evaluated to adopt a hub-and-spoke system for the supply of raw materials.

3.2. CONVERSION

PROCESSING
With regard to biomass treatment, you can refer to paragraph 2.3 on biorefinery types.

3.3. DOWNSTREAM

HIGH-VALUE PRODUCTS
The chemical industry will have to adapt in the short term to raw materials characterized by greater functionality. The development of new biobased polymers allow a better development of new monomers; additives and new processes will be needed for the conversion of "platform" chemical substances in high value products such as:

- fibre-based materials (e.g. for construction or biocomposites for vehicles manufacture or housing);
- bioplastics and other biopolymers;
- surfactants;
- bio-lubricants;
- bio-solvents;
- chemicals and chemical building blocks;
- pharmaceutical products including vaccines;
- enzymes;
- cosmetic ingredients.

Finally, the business location in the vicinity of feedstock suppliers will be an added value, considering the growing propensity of consumers for environmentally friendly materials.

4.
COMMERCIAL BIOREFINING

4.1. INTERNATIONAL SITUATION

The petrochemical industry has been looking for feedstock alternatives and accompanying technologies, as mentioned in paragraph 2.2 "Drivers for biorefinery"; as a result, the call for products based on renewable resources has grown louder in recent years. For instance, Chevron formed a joint venture with Weyerhaeuser (a forest products company) in order to produce fuels, and Royal Dutch Shell is a long-time partner of Iogen, a company that is developing technology for producing second generation bio-ethanol.

Moreover, bio-based industries, like those in the pulp and paper sector, are looking for opportunities to revive their commodity-based business by considering the expansion of their product portfolios with added-value products.

Considerable worldwide investment in technology and biorefining activity is underway demonstrating the economic case for action. According to conclusions in the European Commission's "BREW report" on projected markets for renewable chemicals and biomass supply in the EU, demand seems likely to exceed supply in the near future.

Biorefinery activity worldwide has been driven by the production of bioethanol. Bio-fuels used in transport are currently the most prominent products produced in biorefineries, bioethanol being the most known. Currently, the first producers of bioethanol are the United States, which make it from corn, and Brazil, which uses sugarcane as feedstock.

Biodiesel can be produced from vegetable oils (e.g. from Jatropha, micro-algae, etc.) or from animal fat feedstocks. The biodiesel is formed via trans-esterification of fatty acids contained in these feedstocks into methyl or ethyl esters. It can be used as automotive fuel, heating oil, and has been tested for railway and aircraft usage.

Multi-national companies with active biomass research projects include:

- car manufacturers, such as General Motors (GM), Daimler Chrysler and Volkswagen;
- oil companies, including Shell and BP;
- chemical producers, notably DuPont and Dow;
- agricultural processors, such as Archer Daniels Midland (ADM) and Cargill.

In addition to biofuels, which have been supported by government subsidies for transport use, there is a wide range of bio-based products that can be obtained by biorefining. A list is given in paragraph 3.3, section "High-value products".

The global production capacity for bioplastics has grown about 20% each year in the last decade and currently amounts to 1.4 Mtons. Many countries and world regions have already identified bioplastics as the most promising opportunity for a transition towards a future-oriented bioeconomy. Supportive mechanisms have been established, such as the "Bio-Preferred Programme" in the United States and national investment programs in several countries in South East Asia. Although bioplastics are currently considered a niche market, a growth is expected. The model of bioplastics' fast growth is represented by biodegradable bags and packaging, which will be further examined with a case study in Italy.

The global production capacity of biopolymers by region is represented in Figure 5.

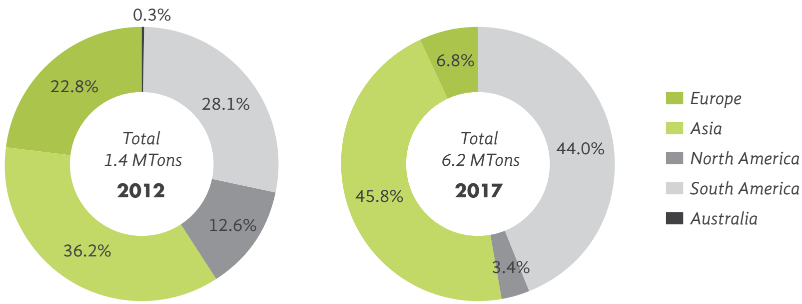

Figure 5. Bioplastics current market and trends. Source: European Bioplastics Association, 2013.

Disposable products in the health sector, detergents, hygiene products, cosmetics and paintings are areas in which the bio-based products could reach a considerable market share. Although markets for the various "platform" chemicals currently produced with bio-based materials show strong growth forecasts, it is not easy to estimate the potential market for new biobased products. However, there is a tendency to focus on existing markets, i.e. markets resulting from the capability of bio-based products to substitute products from other raw materials. The biorefining activity varies from country to country. Below are some details of major operators around the world.

USA

The U.S. government invested heavily on biorefining technology and set an ambitious goal of replacing 30% of their fuel supply with bioethanol from corn by 2030. Most of biorefineries tend to be located in major corn producing states in the Midwest.

BRAZIL

The key factor for Brazilian production is the security of supply and the ability to efficiently use the infrastructure for sugar cane production. Brazil is the cheapest place worldwide for the production of bioethanol, with an output similar to the United States. Many international chemical companies are now locating their production facilities in Brazil to competitively manufacture downstream products, such as bio-polyethylene.

CANADA

Ensyn has many bio-oil commercial facilities in the United States and Canada. The bio-oil is used for energy and chemicals production. Canadian company Dynamotive also produces bio-oil from wood at its facility in Ontario. The same company is now building six pyrolysis plants in Argentina for the production of bio-oil from forest and agricultural residues.

JAPAN

BioEthanol Japan Kansei inaugurated the world's first commercial second-generation cellulosic biorefinery in Osaka utilising wood debris derived from construction waste. The technology was licensed by the U.S. company Celunol.

EUROPE AND ITALY

The shift towards a bioeconomy was recently recognized by the European Commission through the adoption of a dedicated Strategy outlining the need for Europe to move towards a post-petroleum society in order to respond to the key societal challenges the world is set to face in the coming years. The European Commission has also emphasized the pivotal role of biobased products and market development in the context of the review of the EU Industrial Policy.

In February 2012, the European Commission adopted the new "Bioeconomy Strategy" to shift Europe towards a greater and more sustainable use of renewable resources. While the Bioeconomy Strategy itself is a good start, Europe today still remains a long way from establishing optimal framework conditions for the bioplastics industry.

In 2010, about 62% of renewable energy in the European Union was generated from biomass and even if this share is expected to decrease to 57% in 2020, the total bioenergy contribution to the EU mix is expected to increase from 3600 PJ in 2010 to about 5900 PJ in 2020.

The European market for soaps, detergents and other similar products amounted to approximately 30 billion €; between 30 and 50 % of these products contain bio-based enzymes. In Europe, the production of enzymes is strong and it suggests a potential increase of their use in food, paper and textile productions.

Choren in Germany is developing commercial operations using the biomass-to-liquid (BTL) technology. A demonstration plant was built in Freiburg, in collaboration with Shell and using wood as raw material.

The forest resources of Scandinavia are being targeted for the production of cellulosic ethanol. Neste Oil (Finland) with Petrobras (Brazil) are producing diesel from hydrogenated vegetable oils and animal fats at the Porvoo refinery. The NExBTL biodiesel product has interested Total (France) and OMV (Austria).

UOP and ENI are building a new biodiesel facility in Livorno, Italy. The plant will process 6500 barrels per day of vegetable oil utilising the Ecofining technology jointly developed by UOP and ENI. Austria has been developing technology based on grass and silage since 1999 with the aim of exploiting the fibres, proteins and lactic acid components. This is being developed with groups in the Netherlands.

Despite the complex economic crisis affecting Italy since 2009, an economic sector shows remarkable vitality and is now one of the few with positive growth indicators: the "Green Economy". Within this sector is possible to plan and provide a set of possible solutions able to generate new jobs, improve the socio-cultural context and produce environmental benefits. In this scenario integrated biorefineries represent a valuable development opportunity, especially for local communities through the efficient use of local resources. Among key actors of Green Economy in Italy, three companies stand out: Novamont, ENI Versalis, and Biochemtex (Mossi Ghisolfi group).

NOVAMONT innovation strategy is based on the third generation biorefinery concept, and on the approach of a strong multi-disciplinary collaboration with agricultural world, research community and local institutions. In this way the local peculiarities are commended and will maximize the use of waste and residues as valuable inputs and secondary raw materials for biorefineries. Under the brand name Mater-Bi ® Novamont produces and sells various types of biopolymers. The plant components are varied in nature (cellulose, glycerin, natural fillers and non-genetically modified starch obtained from various crops) and are all extracted from plantations neither competing with food production nor occupying especially deforested land.

VERSALIS is a chemical company with sole shareholder, subject to the direction and coordination of Eni SpA. Versalis manages the production and marketing of petrochemical products (basic chemicals, styrenics, elastomers, polyethylene), relying on a range of proprietary technologies, advanced facilities, and a local and efficient distribution network.

BIOCHEMTEX, previously known as Chemtex Italia, is a global leader in the development and engineering of bio-chemical technologies and processes based exclusively on the use of non-food biomass, as an alternative to fossil resources. In partnership with Beta Renewables – of which it is the major shareholder, alongside other shareholders including the US-based private-equity fund TPG and Novozymes, a leading Danish company in the field of bio-innovation – Biochemtex has created technologies and plants for the production of bio-ethanol and other chemical products. Following an investment of 150 million euros and seven years of study, the company completed the design of Proesa®, an exclusive technological platform now marketed by Beta Renewables. Proesa® makes it possible to obtain biofuels and numerous chemical intermediates, and has been implemented on an industrial scale in the plant located at Crescentino, the world's first plant for the production of second-generation bioethanol. Biochemtex is also developing the new MOGHI technology for the conservation of lignin in bio-naphtha and aromatic compounds, which are widely used in numerous industrial sectors. The company, part of the Mossi Ghisolfi Group, is based in Tortona and has two Research Centres in Rivalta Scrivia and Modugno, where the demonstration system for MOGHI technology will be completed by 2014.

CASE STUDY IN ITALY: BIOPLASTIC BAGS

In January 2011, in Italy a law was passed aimed at reducing the environmental pollution caused by traditional plastic bags, through their replacement with biodegradable and compostable bags (in accordance with CEN 13432), in addition to the encouragement to use fabric bags. These ecological solutions have become in no time environmentally friendly alternatives available to consumers and dealers.

A study showed that the use of disposable bags dropped by 50% after the implementation of this strategy, demonstrating that consumers are ready to change their habits quickly, in order to adopt more sustainable behaviors.

This strategy has also limited the occurrence of consequences for the environment, improving the quality of organic recycling and establishing favorable conditions for the growth of a market for bio-based products, which act as primers for new investments in the bio-economy.

Disposable bags are mostly used only once, thus representing a real waste of resources, not to mention the fact that they tend to be dispersed in the environment and, thanks to their strong resistance to biodegradation, they tend to accumulate in, and pollute, the marine environment. Here, in time they are subjected to erosion of mechanical waves, resulting in the formation of microscopic fragments, which can absorb toxic chemicals present in the sea. Since these microscopic fragments of plastic may be ingested by fish and marine mammals, there is a real risk of contamination of the food chain.

4.2. BIG PLAYERS IN ITALY: RELEVANT INDUSTRIAL ALLIANCES

Versalis and Genomatica formalized a technology joint venture agreement to develop a complete end-to-end process for on-purpose production of butadiene from non-food biomass as well as start licensing this technology across Europe, Asia and Africa.

Genomatica is a widely-recognized technology leader for the chemical industry based in California (USA). It delivers new manufacturing processes that enable its partners to produce the world's most widely-used chemicals from renewable feedstocks, with better economics and greater sustainability than petroleum-based processes.

Versalis aims to be the first company to license the process and build commercial plants, thus providing over 20 million dollars in funding to Genomatica to support the end-to-end process. Just like the bio-succinic acid race, the ultimate showdown here is who can produce the most economical bio-butadiene.

The long-term supply outlook for global butadiene is for the market to be tight as forecast say its demand is to outstrip supply because of several reasons: the expected under-utilization of European crackers due to new Middle East capacities; the preference to crack lighter, more competitive feeds in the Middle East and in the US (influenced by shale gas); and not enough dedicated butadiene facilities to cope with future growth in demand especially from BRIC countries.

Versalis has partnered with tire manufacturer Pirelli to develop the use of guayule in tire production. Pirelli will carry out trial tests under the three-year research project to validate the performance of the natural rubber for tire production. As soon as new industrial quantities become available, Versalis will supply Pirelli with guayule from Yulex to complement the current set of synthetic rubber materials that they already supply to Pirelli for the production of conventional tires.

Figure 6. The Genomatica CEO Christophe Schilling (top row, third from the right) and Versalis CEO Daniele Ferrari (top row, third from the left).

Pirelli said has been already producing tires using renewable materials such as rice husk. The tire industry is really stepping up its game when it comes to using bio-based materials for tire manufacture.

MATRÌCA is a 50:50 joint venture between Versalis and Novamont. The innovative business combines their complementary experience in a joint venture which is entirely dedicated to the development and manufacture of a new range of products that are based on renewable raw materials and that have low levels of environmental impact.

Figure 7. Porto Torres, plant under construction. Source: Matrica website.

The "Polo Verde" (Green Hub) at Porto Torres will serve as an international model for the entire sector and is marked out by a highly distinctive feature in the form of the integration of the production chain, thanks to the cultivation across the territory of crops that will be used for the production of biomass - the raw material for bioproducts. The biomass crops are cultivated in outlying areas that would not otherwise be utilised.

The project will be implemented with a total investment of approximately 500 million euros and will include the construction of various plants for the production of bio-monomers, biolubricants and bio-additives for elastomers. The operation covers a total area of about 27 hectares. Two plants will go onstream as soon as the first months of 2014.

The Matrìca plants will produce, amongst other products, monomers, polymers and additives for lubricants obtained from renewable sources.

This series of products takes its cue from a process - being applied for the first time on an industrial scale; it has been developed thanks to Novamont's research in the use of vegetable oil as a raw material.

BETA RENEWABLES is a leader in the field of advanced biofuels and biochemical compounds at competitive costs. It was established at the end of 2011 as a joint venture between Biochemtex, a company of the Mossi Ghisolfi Group, and the U.S. fund TPG (Texas Pacific Group) with a total investment of 250 million Euro (350 million dollars). At the end of 2012, Novozymes – world leader in the enzymes industry – became a shareholder of Beta Renewables, with the acquisition of 10 percent of the shares, amounting to 90 million Euro. Beta Renewables manages the plant in Crescentino, the first commercial facility in the world for the production of second-generation ethanol. The plant was carried out by Biochemtex and is entirely based on the Proesa™ technology, also developed by Biochemtex; at full capacity, the plant will produce 60,000 tons of bioethanol per year.

Proesa™ is a flexible technology able to produce bioethanol from a variety of different lignocellulosic biomass feedstocks. The project was supported by the European Commission under the Seventh Framework Programme for research and technological development. The bioethanol produced at Crescentino is purchased by one of the major global oil companies and distributed on the European markets, in addition to supplying one of the service stations in Tortona.

REVERDIA is a joint venture between Royal DSM, the global Life Sciences and Materials Sciences company, and Roquette Frères, the global starch and starch-derivatives company. Reverdia is dedicated to be the global leader in the market for sustainable succinic acid, focusing on market development by establishing partnerships with direct and indirect customers, building on customer needs and Reverdia strengths. Combining the knowledge and experience of DSM and Roquette, Reverdia produces and sells Biosuccinium™, the Company's registered brand of biobased succinic acid. Biosuccinium™, which is produced using a unique and proprietary low pH yeast technology, enables customers to produce bio-based, high-quality performance materials while at the same time substantially improving their environmental footprint.

Reverdia began construction in 2011 of a commercial scale plant for the production of biobased succinic acid, the first non-fossil feedstock derived chemical building block that allows customers in the chemical industry to choose a bio-based alternative for a broad range of applications, from packaging to footwear.

This novel plant is backward-integrated with the biorefinery-producing C-source. It is built on the premises of Roquette in Cassano Spinola. Operations at the plant where started in December 2012.

The new commercial production facility in Italy will be producing bio-based succinic acid using fermentation technology. The proprietary yeast-based fermentation process allows succinic acid to be produced with a significantly higher energy efficiency compared to the traditional method. It is also one of the first bio-based processes that sequesters carbon dioxide in the production process.

The site will employ the co-generation of steam and electricity and on-site waste water treatment. Its proximity to Genoa's harbour also ensures efficient global logistics.

Figure 8. Reverdia commercial plant site in Cassano Spinola, Italy. Source: Reverdia website.

AGRI-FOOD INDUSTRY AND PLASTICS ALLIANCE TAKE OVER THE BIOTECHNOLOGY-BIOBASED SECTOR: THE BIOSPHERE CASE IN EMILIA-ROMAGNA

Biosphere is an Italian small-medium enterprise focused on development and production of free and immobilized enzymes, microbial biomass and metabolites currently applied in several processes in the pharma, food, nutraceutic and cosmetic sectors. The activities include research and development of bio-molecules obtained from natural sources (microorganisms and plants) with a particular focus on the use of by-products from the agri-food sector as sources of high value biochemical compounds. The mission of Biosphere is to develop know how and expertise in the fields of fermentation and bioprocesses in order to be a preferred biotech partner, delivering customized contract of R&D and of manufacturing services, providing tailor-made and cost-effective solutions for a wide range of industrial applications. Fermentation, bioprocesses and extraction of molecules from natural sources are gradually replacing chemical processes based on fossil fuels, as bioprocesses are far more efficient than traditional chemical synthesis, in terms of selectivity, energy use and environmental sustainability. Biosphere was founded in 1999 as the biotechnology division and R&D center of SFIR Group, a leading Italian player in the sugar industry. In 2002 Biosphere became an independent company after the development of new projects and the start of the production activities. In 2012 Orogel SpA, Softer SpA and Ayrion Sustech SpA became new shareholders of the company, together with SFIR SpA.

OROGEL S.p.A. Consortile is the italian leader in production and marketing of frozen products and among the leading producers of fruits and vegetables in Italy. The company is based in Cesena, Italy. Orogel S.p.A. Consortile, which has 455 employees and an annual revenue of 188 million euros, operates as a subsidiary of Orogel Societa' Cooperativa Agricola.

SO.F.TER. GROUP is one of the largest independent compounders in the world. The company's product range, one of the largest in Europe, includes thermoplastic elastomers,thermoplastic vulcanizates and engineering plastics. Products: customers innovative, tailor-made solutions with high specialization in the automotive, domestic appliance, construction, footwear and sport sectors. The SO.F.TER. Group, based in Forlì, Italy, has four manufacturing plants in Italy, two in Latin America (Mexico, Brazil), and a sales office near Stuttgart (Germany).

SFIR GROUP S.p.A. (SFIR-Societa Fondiaria Industriale Romagnola) is a privately held company that operates in the confectioners industry. Euro Sfir Italia S.p.A. headquarters are located in Cesena, Italy.

5.

BIOREFINING OPPORTUNITIES IN EMILIA-ROMAGNA

Figure 9. The Biosphere plant in Cesena. Source: Biosphere website.

In Emilia-Romagna, the annual production of biomass from waste, residues and byproducts is estimated to be approximately 20 million tons (Mton/y)[1], of which about 1 Mton/y is wood biomass from forests and forest residues. Only a small part of this important availability is used for the purpose of energy production, and an even smaller fraction of this flow of biomass is addressed to the production of high added value materials (such as polymers, resins, solvents and building blocks for the synthesis of materials), or compounds which can substitute the ones entirely derived from fossil sources.

5.1. FEEDSTOCK FROM WASTES, RESIDUES AND BYPRODUCTS

Origin of biomass can be considered as follow:

- urban wastes,
- agricultural, zootechnical and agro-industrial residues,
- forest residues after forest cleaning.

URBAN WASTES

The organic fraction of municipal solid waste (MSW) is composed of:

- a part called "wet", which includes kitchen and table scraps (fruit, vegetables, meat, fish, bread, eggs, cheeses, pastries, coffee groun-

1. This is a conservative appraisal of the total bulk biomass available in one year; the data is extrapolated from the work of CIRI-CRPA (2011) and ENEA (2006).

ds, tea bags, etc.) and some garden waste (grass, leaves, flowers, twigs, extinguished wood ashes, etc.); this fraction is indicated by EWC (European Waste Code) 200108;
- a part called "green", which includes large pruning, cuttings and garden waste; this fraction is identified with EWC 200201.

Overall, it represents almost one third by weight of municipal waste produced in Emilia-Romagna region. The organic fraction collected in a differentiated manner is screwed to composting (or anaerobic digestion and composting) plants for the production of quality compost. The production and use of compost therefore provides a unique solution to two problems: give preference to those forms of waste management that provide for the recovery of materials (and allows you to limit the environmental impact of waste), and encouraging the use of organic amendments to the soil to compensate for the increasing shortage of organic matter. The 20 plants operating in Emilia-Romagna in 2011 dealt mainly urban organic waste, for a quantity of 515,636 tons (compared with a maximum authorized capacity of 629,770 tons), of which 58% is wet, 33% is green, 4% is sewage sludge and 5% comes from other compostable fractions.

A) WET

The 233,852 tons of wet organic waste produced in 2011 correspond to a quantity of 52 kg per capita. Of these, 232,647 tons were collected by the operators of municipal collection services, while 1,205 tons, almost all from food industries of the province of Ravenna, consist of assimilated wet waste that manufacturers sent directly to recovery. A share of 74% of the amount collected by municipal collection services was sent directly to composting facilities, while the remaining 26% passes, as first destination, in storage and/or selection facilities to be subsequently transferred to plants for composting. Data at the provincial level for 2011 show big differences: it goes from 28 kg per inhabitant of Reggio Emilia to 107 kg per inhabitant of Rimini. These differences are due to prevalence and geographical coverage of collection services. In the case of Rimini, the high value is related to the contribution of hotels and restaurants. The yield of interception at the regional scale is about half (51%) than the quantity which is assumed to be present in the waste products, therefore there is still ample room for improvement.

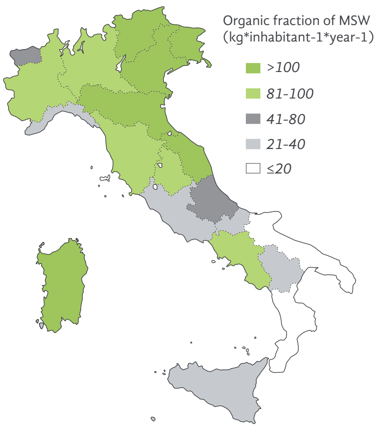

Figure 10. Waste intensity of the organic fraction of urban waste expressed as the sum of wet and green fractions, in kgkilograms per inhabitant per year. Source: ISPRA, Municipal Solid Waste report, 2013 edition.

B) GREEN

353,735 tons of green waste intercepted in 2011 correspond to a quantity of 79 kg per capita. Of these, 347,438 tons were collected by the operators of municipal collection services, while 6297 tons, almost all in the province of Rimini, consist of assimilated green waste that manufacturers sent directly to recovery. A share of 54% of the amount collected by municipal collection services was sent directly to composting facilities available in the region (only 5% is sent outside the region), while the remaining 46% passes, as first destination, in storage and/or selection facilities (43% regional and 3% extraregional) to be subsequently sent to composting plants or other recovery facilities (paint brush production plants, pelletization plants, etc.). The first destination plants are mainly located in the region. The trend in the last 10 years has seen a significant increase: per capita share has more than doubled. Data at the provincial level for year 2011 show big differences, ranging from the minimum value represented by 36 kg per inhabitant of Bologna to the maximum represented by 147 kg per inhabitant of Reggio Emilia. Such significant changes are related not only to the different distribution of the collection, but also the criteria of assimilation under which it is possible to extend to companies operating in the horticultural industry the possibility of conferring the green fraction to urban waste collectors and count as municipal waste those arising from the maintenance of public parks. The yield of interception of the green waste is equal to 73%, a good result that can be further improved.

Province	**MSW, organic fraction, "wet" part (t*year-1)**	**MSW, organic fraction, "green" part (t*year-1)**	**MSW, organic fraction, total (t*year-1)**	**UCO (t*year-1)**
Piacenza	*13822*	*22128*	*35950*	*92*
Parma	*26031*	*43288*	*69319*	*52*
Reggio Emilia	*15189*	*78494*	*93683*	*88*
Modena	*40898*	*46642*	*87540*	*159*
Bologna	*40326*	*36015*	*76341*	*138*
Ferrara	*18514*	*33255*	*51769*	*76*
Ravenna	*16402*	*44953*	*61355*	*95*
Forlì - Cesena	*27156*	*23997*	*51153*	*47*
Rimini	*35515*	*24962*	*60477*	*25*
Emilia-Romagna	***233852***	***353735***	***587587***	*773*

Table 1. Organic fraction from Municipal Solid Waste (MSW) and collected Used Cooking Oils (UCO) (see paragraph 5.2) in the waste management facilities; quantities per province. Source: Regione Emilia-Romagna and ARPA Emilia-Romagna, "La gestione dei rifiuti in Emilia-Romagna – Report 2012".

AGRICULTURAL, ZOOTECHNICAL & AGRO-INDUSTRIAL WASTES

Emilia-Romagna region is a leader in Europe with regard to agriculture and farming (especially pig and poultry sector), and related agro-industrial activities. Because of the importance and size of this area, the whole waste management must be approached very carefully to prepare specific projects for energy and matter recovery of these important quantities.

Looking more specifically into the agricultural sector, the most interesting crops are fruit and grapes, horticultural crops, tuber plants, legumes, wheat, maize and sorghum. Nevertheless, the predominant activity is the tomato processing, in which Emilia-Romagna region is the second most important in Italy.

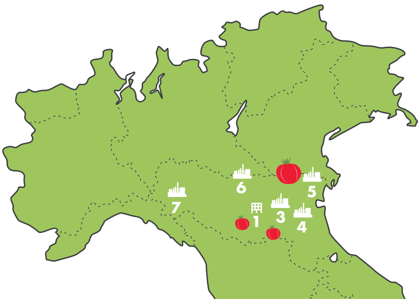

Figure 11. Main plants location of Conserve Italia, the leader in tomato processing in Italy. Source: Conserve Italia website.

Tomato residues play an important role in the agro-industrial residues budget (see table 2).

AGRO-INDUSTRIAL BIOMASS AVAILABILITY

Province	Industrial tomato production (t*year-1)	Industrial tomato potential residues (t dm*year-1)
Piacenza	*711940*	*11320*
Parma	*286359*	*4553*
Reggio Emilia	*48360*	*769*
Modena	*39825*	*633*
Bologna	*24020*	*382*
Ferrara	*419420*	*6669*
Ravenna	*100608*	*1600*
Forlì - Cesena	*4829*	*77*
Rimini	*1500*	*24*
Emilia-Romagna	***1636862***	***26026***

Table 2. Agro-industrial availability of tomato processing residues upstream (e.g. discarded tomatoes) and downstream (e.g. peels, seeds, etc.) in year 2010. Source: Osservatorio Agroalimentare, 2010.

As regards the dairy sector too, Emilia-Romagna is among the most productive italian regions; regional production of cow milk is about 1.77 million tons. The main byproducts are whey, "scotta" (from production of ricotta cheese) and buttermilk (from production of butter). Among these, the major by weight is definitely whey; its production varies, depending on the type of cheese obtained (hard cheese, semi-hard cheese, soft cheese and fresh cheese) from 75 to 90 % of the weight of milk sent to transformation. Since in Emilia-Romagna milk is largely used for the production of Parmigiano Reggiano and Grana Padano, which are hard cheeses with relatively low production yield of whey, we can estimate a production of approximately 1.45 million tons of whey and buttermilk.

AGRICULTURAL BIOMASS AVAILABILITY

Province	Straw (t*year-1)	Pruning vines (t*year -1)	Rice hull (t*year -1)	Vinasse (t*year -1)	Olive pomace (t*year -1)	Agricultural residues, total (t*year -1)
Piacenza	*176785*	*19227*	*0*	*3969*	*0*	*199981*
Parma	*136298*	*4093*	*0*	*855*	*0*	*141246*
Reggio Emilia	*98890*	*53390*	*36*	*10857*	*0*	*163173*
Modena	*226305*	*59079*	*297*	*8964*	*0*	*294646*
Bologna	*281168*	*54267*	*183*	*6160*	*0*	*341777*
Ferrara	*364044*	*27058*	*7843*	*773*	*0*	*399718*
Ravenna	*188240*	*117026*	*0*	*22211*	*0*	*327477*
Forlì - Cesena	*63060*	*49945*	*0*	*6011*	*0*	*119016*
Rimini	*21760*	*14374*	*0*	*2242*	*574*	*38950*
Emilia-Romagna	***1556549***	***398458***	***8359***	***62043***	***574***	***2025983***

Table 3. Agricultural biomass availability per province (elaboration on data available in 2006). All weights are expressed as dry matter.
Source: ENEA, Report RSE/2009/167 "Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS".

ZOOTECHNICAL FERMENTABLE BIOMASS AVAILABILITY

Province	Solid manure, cattle (t*year-1)	Solid manure, pork (t*year-1)	Solid manure, total (t*year-1)	Liquid manure, pork (m3*year-1)
Piacenza	*141829*	*13783*	*155611*	*300156*
Parma	*295644*	*20372*	*316016*	*474241*
Reggio Emilia	*264589*	*32412*	*297001*	*750315*
Modena	*176158*	*38025*	*214183*	*857449*
Bologna	*58135*	*2983*	*61118*	*66924*
Ferrara	*36446*	*37*	*36483*	*823*
Ravenna	*15818*	*766*	*16584*	*18551*
Forlì - Cesena	*34363*	*7379*	*41742*	*159116*
Rimini	*4456*	*189*	*4645*	*3659*
Emilia-Romagna	***1027437***	***115947***	***1143384***	***2631233***

Table 4. Zootechnical fermentable biomass availability per province (elaboration on data available in 2006). All weights are expressed as tonns per year of bulk material, except liquid manure pork expressed as cubic meters per year.
Source: ENEA, Report RSE/2009/167 "Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS".

Digestable slaughter waste, cattle (t*year-1)	Digestable slaughter waste, pork (t*year-1)	Digestable slaughter waste, sheep & goat (t*year-1)	Digestable slaughter waste, total (t*year-1)
3207	*11751*	*14*	*14971*
2236	*21823*	*14*	*24072*
10613	*20144*	*10*	*30767*
12466	*25180*	*15*	*37661*
453	*15108*	*10*	*15570*
34	*0*	*0*	*34*
3115	*5036*	*2*	*8153*
251	*10072*	*8*	*10331*
139	*0*	*0*	*139*
32513	***109113***	***72***	***141698***

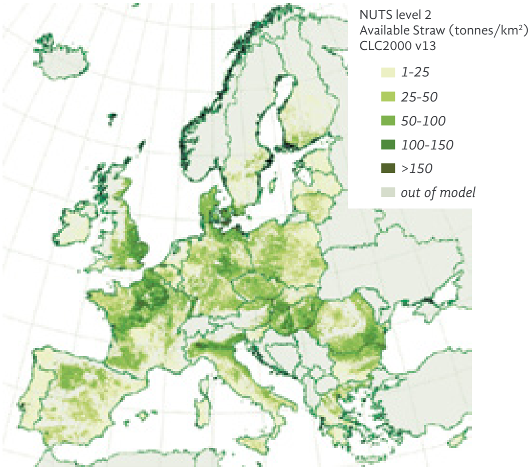

Figure 12. Agricultural straw residues per square kilometer potentially available for energy use in EU-27. Source: Monforti et al. 2013, "The possible contribution of agricultural crop residues to renewable energy".

FORESTRY

Forest residues consist of small trees, branches, tops and un-merchantable wood left in the forest after the cleaning, thinning or final felling of forest stands, used as solid fuel without any intermittent applications. Three main sources of forest residues can be distinguished: slash from final felling, slash and small trees from thinning and cleanings, and un-merchantable wood.

ACCESSIBLE WOODY BIOMASS AVAILABILITY FROM FORESTRY

Province	Broad-leaves woods (t*year-1)	Conifer woods (t*year-1)	Arboriculture (t*year-1)	Total woody biomass (t*year-1)
Piacenza	*26074*	*222*	*13709*	*40005*
Parma	*54686*	*364*	*15339*	*70390*
Reggio Emilia	*21692*	*87*	*10964*	*32742*
Modena	*23178*	*344*	*2003*	*25526*
Bologna	*35471*	*335*	*1518*	*37324*
Ferrara	*1005*	*223*	*6869*	*8097*
Ravenna	*1772*	*1633*	*161*	*3567*
Forlì - Cesena	*17397*	*914*	*0*	*18311*
Rimini	*560*	*20*	*0*	*580*
Emilia-Romagna	***181835***	***4144***	***50563***	***236542***

Table 5. Forest residues availability per province (elaboration on data available in 2006). Source: ENEA, Report RSE/2009/167 "Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS".

5.2. USED COOKING OILS

A special discussion deserves the category of used cooking oils (UCO; EWC 200125), a type of potentially very polluting waste whose collection and recovery is still not fully operational in Italy. The collectors members of CONOE (Mandatory National Consortium for Exhausted Oil) in Emilia-Romagna collected 12,672 tons of UCO in 2010; the share coming from the separate collection of municipal waste must be added, which in 2011 was 773 tons in the region. These quantities are a strong underestimation of the amount of UCO actually produced annually in the region; in fact, it is not considered the portion not intercepted either by CONOE nor by the municipal waste management. The missing portion is only partially collected by operators not registered with the national consortium (although mandatory): a considerable part of UCO continues to be spilled into sewage systems causing problems and additional costs for the treatment of wastewater, if not directly into the environment causing problems of pollution of soil, surface water and groundwater.

The quantities produced at the national level estimated by CONOE amount to 280,000 tons per year, of which 160,000 tons from households, 70,000 tons from catering, and 50,000 tons from food industry. These estimates, compared to regional data, show that the share of missing UCO is probably well above 50%. The exhausted oils and fats undergoing regeneration are used to produce:

- methyl esters for biodiesel (> 50% of total regenerated quantity);
- lubricants for agricultural machinery (20%);
- fats for industry (10%);
- energetic recovery, alone or combined with other fuels (10%);
- the remaining 10% is divided between glycerin for saponification, release agents for construction and other industrial products. The processing waste is estimated between 10 and 12%.

For figures, see Table 1, column UCO.

5.3. CURRENT USE OF BIOMASS IN THE AGRICULTURE SECTOR

In this section an assessment of the agricultural sector in Emilia-Romagna region is carried out with the aid of data from the General Census of Agriculture in years 2000 and 2010. In these 10 years the following trends are registered:

- a decrease in the number of active companies (106,000 in 2000 in comparison with 73,441 in 2010), the decline of both young farmers (-47.7 %) and Usable Agricultural Area (UAA) in the mountain areas (-20 %);
- an increase in both the average business size (from 10.65 hectares in 2000 to 14.63 in 2010) and in the average number of all animals raised in stables (i.e. cattle, rose from 52 to 76 per stable).

The number of active farms in the region are 73,441 accounting for a UAA of 1,066,773 Ha. With reference to the year 2000, farms dropped by 31 % (-32.2 % in Italy) and the total UAA decreased of 5.5 % (-2.3 % in Italy); as an opposite trend, the average UAA per farm increased by more than a third: from 10,65 Ha in 2000 to 14,63 in 2010, twice the Italian average of 7,93 Ha.

These trends differ according to elevation range: in the mountains the number of farms dropped by 42% and UAA shrunk by 20 %, in the hills by 32 % and by 11% respectively and in the plains by 28 % and by 0.8% respectively.

The loss of UAA in 10 years has been of 62,000 hectares, however the average annual production capacity of regional farms remained essentially unchanged. This demonstrates a hold of regional production despite the fact that a significant share of agricultural and forest land (171,000 hectares) were allocated to agro-environmental measures for the protection of biodiversity, water resources and soil, and for mitigation of climate change. The regional average farm's UAA grew by more than a third, which means that the big companies increased in number: those with an UAA between 50 and 100 Ha grew by 14.2 %,and those over 100 Ha grew by +33.7 %. In summary 3,958 companies (5.4 % of the total) control or owns 42 % of the UAA (this share was 32 % in year 2000). If we also consider companies with more than 30 Ha, this share rises to 56 %. As regards the use of UAA in 2010, 78 % (corresponding to 813,756 Ha) was occupied by arable land, ranking Emilia-Romagna first region in Italy; 12 % is occupied by tree crops production and 10 % by permanent grassland. A share of 72 % of arable land is concentrated in the plains, increasing by about 11,000 Ha compared to year 2000, while a drop of 38,000 Ha was recorded in the hilly and mountaineous areas. For tree crops, conversely, the reduction is more sensitive in the plains.

Cereals, forage alternated, grain legumes, vegetables, seeds and seedlings are all crops earning surfaces with reference to year 2000. The sugar beet registered a sharp decline: the current surface is about one third of that occupied in year 2000. Also industrial crops are declining, most likely as a result of the downsizing of soy, while fallow land almost halved after the end of mandatory "set-aside" practice. Among tree crops, it is worth noting the significant decrease (about 22 %) of fruits. Even the vines decreased of approximately 7.1 %, reaching about 56,000 Ha.

Crops Type	Acreage		Variations [%]
	2010	**2000**	
Cereals	*372569*	*363782*	*2,4*
Legumes	*5203*	*3962*	*31,3*
Potatoes	*5251*	*4878*	*7,7*
Sugar beet	*24984*	*71531*	*-65,1*
Fodder roots and brassicas	*314*	*116*	*171,3*
Other crops (Fibres)	*31501*	*47711*	*-34*
Horticultural	*49173*	*43920*	*12*
Flowers and ornamental plants	*452*	*487*	*-7,3*
Seedlings	*657*	*528*	*24,4*
Forage alternated	*296383*	*284884*	*4*
Seeds	*9969*	*5959*	*67,3*
Fallow land	*17300*	*31898*	*-45,8*
Crops	***813756***	***859656***	***-5,3***
Vine	*55695*	*60072*	*-7,3*
Olive	*3661*	*2644*	*38,5*
Fruits	*67137*	*86041*	*-22*
Nurseries	*2280*	*2151*	*6*
Other tree crops	*404,8*	*11*	*3580*
Greenhouses	*10*	*372*	*-97,5*
Woods/Plantations	***128941***	***151290***	***-14,8***
Horticulture Gardens	*1459*	*1359*	*7,3*
Permanent grassland and meadows	***98556***	***117012***	***-15,8***
Surface agric. used	***1046596***	***1129,32***	***-7,3***
Total Area (1)	***1341196***	***1462985***	***-8,3***

Table 6. Cultivated land by type in Emilia-Romagna. Source: ISTAT, 6th General Census of Agriculture – Provisional data.
(1) Usable Agricultural Area (UAA) plus the surface intended to forests, trees for wood, UAA unused and other surfaces.

POTENTIAL FOR CHANGE

According to Campbell et al. (2013) converting actual croplands and agricultural lands in bioenergy agriculture could accelerate climate change by emitting carbon stored in forests, while converting food agricultural lands in bioenergy agriculture could threaten food security. Both problems are potentially avoided by using abandoned agricultural lands for bioenergy agriculture. Biomass cultivation on abandoned agricultural lands is thought also to reduce land use impacts relative to biomass production on currently used croplands.

According to the National Institute for Agriculture Economics (INEA) abandoned lands are those temporarily unexploited lands suitable for farming recovery by ordinary agricultural practices, excluding land clearing and trenching.

In the Emilia-Romagna region there are 35,000 Ha of unexploited land (ISTAT, 2012).

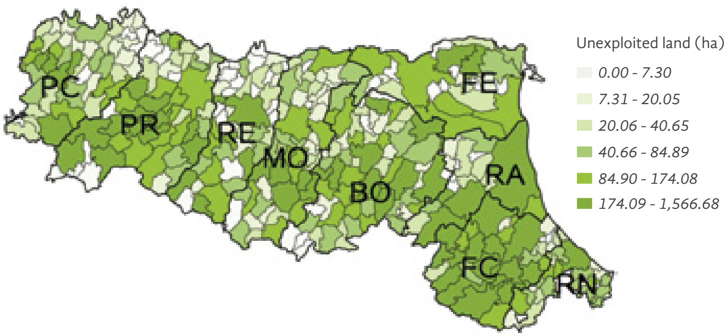

Figure 14. Unexploited land at municipal level in Emilia-Romagna. Source: ISTAT, 2012.

In addition, a recent analysis conducted by CRPA in 2011 showed that, according to available data, in the Emilia-Romagna region the annual biomass residues potentially exploitable for energy production amounted to 2.6 million tons of ligno-cellulosic biomass and 16 million tons of food and animal waste. This potential can be exploited by different supply chains depending on the type of biomass, the technology used and the desired output products.

6.
POTENTIAL PRODUCTS

The biorefinery output comprises a wide range of chemical products. Taking as an example the thermochemical processes, using syngas you can duplicate all of the conventional products of the petrochemical industry. The fermentation gives rise to a range of already marketed platform chemicals, or substitutes for existing materials, or new materials for which the market has not fully developed yet.

A careful analysis of types and quantities of feedstocks present in Emilia-Romagna, also in terms of logistics and land development, may allow for the creation of well integrated biorefineries in the region.

The Emilia-Romagna equipment includes already several biogas plants. The fermentation pathway, implemented by the anaerobic digestion, allows for the conversion of most biomass into fermentable sugars, which can in turn be converted in metabolites classified by the number of carbon atoms in the main chain and give rise to bio-based high-value added products: biodiesel, bioplastics and more.

The platform chemicals currently in full-scale production from biomass are:

- ethanol;
- acetic acid;
- lactic acid, and the polymer derived from it - polylactic acid (PLA);
- 1,3 - propanediol - used in polytrimethylene terephthalate (PTT);
- xylose - produced from hardwood and mainly used to produce Xylitol as a sweetener;
- furfural - produced in volume from a range of materials including corncobs, cottonseed hull bran, oat hulls;
- sorbitol - produced by hydrogenation of dextrose.

THE BIOREFER PROJECT

BiorefER is a knowledge-based tool intended for decision making on biorefineries and biobased value chains applied to a regional scenario. The tool is divided into two parts.

Part 1 consists of evaluation tools. Their purpose is to measure and assess the value chains integration and the biorefinery output capacity. A first application in Emilia-Romagna region considered some value-chains based on vegetable oils (palm, rapeseed and sunflower oils), and biogas and biomethane production from maize and manure. Two indexes are used: supply chain activation index (SCAI) and biorefinery index (BI). SCAI index is intended to measure the diversity of economic activities along the value chain by way of statistical NACE (National Classification of Economic Activities) European codes. BI index measures the diversification of products (e.g. power, heat, biochemicals, biomaterials, food and feed) obtained along a biomass-based value-chain; a weight is assigned to each different kind of products to get a unique weighted index. The indexes are first tested in the Emilia-Romagna region, in Northern Italy, where a strong interest in bioenergy is observed and highlighted both in the Regional Energy Plan (Regione Emilia-Romagna, 2013) and by the industrial research regional network (Rete Alta Tecnologia della Regione Emilia-Romagna, 2012). The latter identifies White Biotechnologies as one of 6 pillars for future development.

Part 2 deals with potential biorefineries and aims to foster sustainable and versatile biomass based value-chains. The key concept is the implementation of a geo-referenced Biorefinery Database at regional scale, in order to sketch a picture of relevant elements for future bio-based chains and of their spatial distribution.

Elements include biomass production and related activities (upstream side), primary and secondary treatment systems (conversion activities), marketable products and related distribution systems (downstream side). The Biorefinery Database to date includes more than 110 entities and more than 150 geo-referenced sites belonging to different categories:

- upstream (biomass producers);
- conversion (companies providing primary conversion);
- downstream (companies that create and deliver bio-based products or provide equipment for this sector);
- multiplier organization (trade associations, consortia, holdings);
- public authority (competent public authorities);
- research (industrial research activities);
- service provider (consultancy, intangible services).

BiorefER is an initiative lead by CIRI ENERGIA E AMBIENTE Interdepartmental Industrial Research Center - Energy and Environment - Biomass unit of the University of Bologna.

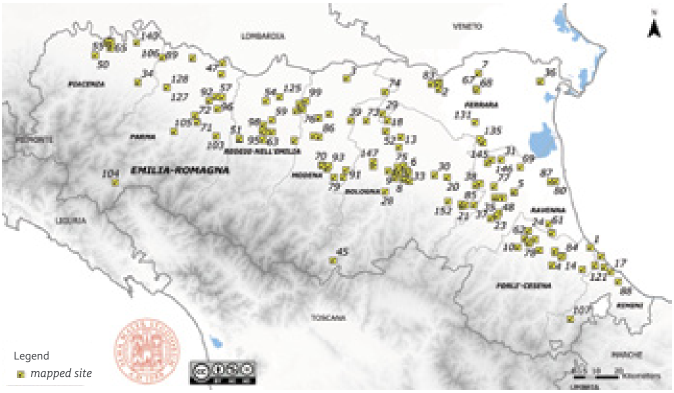

Figure 15. Map of surveyed sites of BiorefER project; the number refers to the identifier code (ID) in the database. One may notice a concentration of sites nearby the provincial capitals, along the National Route 9 (Via Emilia), in the lower Po Valley between the provinces of Reggio Emilia, Modena and Bologna, and in the "lower Romagna" (province of Ravenna, on the borderline with Bologna and Ferrara provinces).

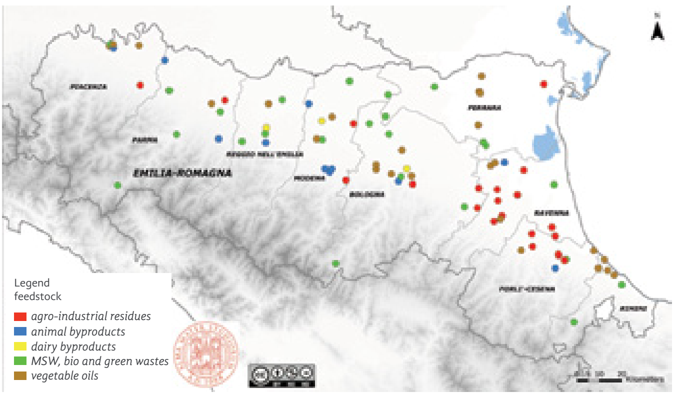

Figure 16. Map of surveyed sites of BiorefER project related to the feedstock and organized by category of waste residues and byproducts producers.

6.1. BIOPLASTICS

According to European Bioplastics[2], the term bioplastics encompasses a whole family of materials which differ from conventional plastics inasmuch as they are biobased, biodegradable, or both.

Bioplastics already play an important role in the fields of packaging, agriculture, gastronomy, consumer electronics and automotive to name a few. In these market segments, bioplastic materials are used to manufacture products intended for short term use, such as mulch films or catering products, as well as durable applications, such as mobile phone covers or interior components for cars.

Bioplastics currently on the market are mainly composed of flour or starch from corn, wheat or other grains. In addition to being biobased, some bioplastics are also compostable, in so far as they meet the requirements specified by the European standard EN 13432 and by certification programs released by leading international bodies. The terminology used in the bioplastics sector is sometimes misleading: while most people use the term bioplastic to mean a plastic produced from a biological source, there is no such a general agreement on biodegradability. All (bio- and petrochemical-based) plastics are technically biodegradable, meaning they can be degraded by microbes under suitable conditions. However, many degrade at such slow rates that they are to be considered non-biodegradable. Some biodegradable petrochemical-based plastics may be used as an additive to improve the performance of many commercial bioplastics. On the contrary, non-biodegradable bioplastics are referred to as durable. The degree of biodegradation varies with temperature, polymer stability, and available oxygen content. Consequently, most biobased plastics will only degrade in the tightly controlled conditions of industrial composting units. The European standard, EN 13432, defines how quickly and to what extent a plastic must be degraded under industrial composting conditions for it to be called compostable. There is no standard applicable to home composting conditions.

The term "biodegradable plastic" has also been used by producers of specially modified petrochemical-based plastics which appear to biodegrade. This type of plastic may be referred to as degradable plastic or oxy-degradable plastic or photodegradable plastic because the process is not initiated by microbial action. While some degradable

2. The association representing the interests of Europe's bioplastics' industry.

plastics manufacturers argue that degraded plastic residue will be attacked by microbes, these degradable materials do not meet the requirements of the EN 13432 commercial composting standard. There are two main advantages in the use of plastics from biomass compared to their traditional versions: they save non renewable resources and they are almost carbon neutral. In addition, the biodegradability is an add -on of the properties of some types of bioplastics.

POLY-HYDROXY-ALKANOATES (PHA)

The polyhydroxyalkanoates (PHAs) are thermoplastic polyesters synthesized by various types of bacteria, such as Bacillus, Pseudomonas and Rhodococcus, through the fermentation of sugars or lipids.

Under certain culture conditions, these linear macromolecules accumulate in bacteria in the form of microscopic granules, reaching high concentrations up to 90% of the dry weight of the bacterial mass. The alkyl group can have a number of carbon atoms between 1 and 15, can be linear or branched and can contain various types of substituents depending on the bacterial strain. For example, bacteria of the genus Ralstonia produce short side chain (1-5 carbon atoms), while Pseudomonas produce medium-sized side chain (more than 5 carbon atoms). The great variability of the side chains of single monomers gives these materials extremely variable physical characteristics: for example, melting point varies between 40 and 180° C. These materials are biodegradable and are used in the production of bioplastics.

Also mechanical properties and biocompatibility of PHAs can be modified, by tweaking the surface or by combining it with other polymers, enzymes, and inorganic materials. The biosynthesis of PHA is usually obtained by special culture conditions, such as lack of nutrients like phosphorus, nitrogen and trace elements, or by lack of oxygen and excess supply of carbon sources. These polyesters concentrate in the bacterial cells in the form of granules with a high refractive index. Depending on the microorganism and culture conditions, homo-or co-polyesters are synthesized with different acid hydroxyalcanoates. The PHA that granules are then recovered by destroying the cells.

The polyhydroxyalkanoates are thermoplastic polymers, can be processed with conventional equipment; they are ductile and elastic, with variable properties according to their chemical composition (homo-or co-polyesters).

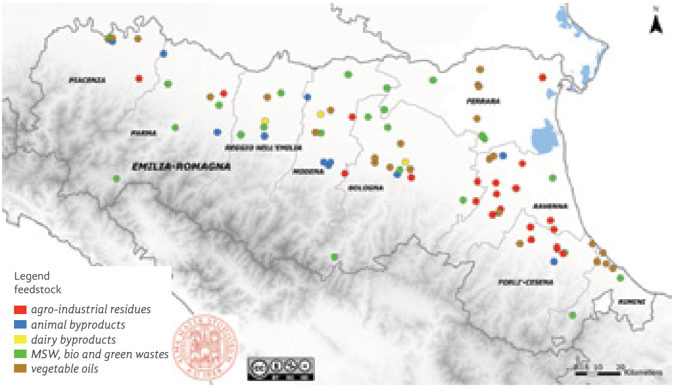

Figure 17. Map of surveyed sites of BiorefER project related to the value chain of PHA-like plastics production from agri-food industry wastes and residues, by category of classification.

PHAs are stable to UVs, unlike other types of bioplastics such as polylactic acid, and show a low water permeability. Polyhydroxyalkanoates are soluble in halogenated solvents such as chloroform or dichloroethane. Their crystallinity can vary from small percentages up to 70%. Their processability, impact resistance and flexibility improve with a higher percentage of valerate in the material.

Among the polyhydroxyalkanoates, polyhydroxybutyrate (PHB) has similar properties to polypropylene (PP), and has a good moisture resistance. The polyhydroxybutyric acid, synthesized from pure PHB is relatively fragile and rigid, whereas copolymers of PHB, which may include other fatty acids such as acid beta-hydroxyvalerate, can have more elastic properties.

POLYLACTIC ACID (PLA)

The polylactic acid, or polylactate, is the polymer of lactic acid. The synthesis is done through several phases: separation of the fibers and gluten; liquefaction and saccharification; fermentation with re-use in the culture medium of the protein separated from starch; purification and concentration of saline solutions of lactic acid; polymerization.

The industrial fermentation takes place thanks to a bacterium of the genus Lactobacillus; it must be used in high purity to avoid influence on the optical purity of the acid produced. Sugar, molasses and whey are used as raw materials. Bacillus coagulans is alternatively used for PLA synthesis. Polylactic acid has properties intermediate to those of PET and polystyrene. As for the biodegradability, hydrolysis occur under conditions of temperature higher than 60° C and humidity greater than 20%.

REFERENCES AND TEXT SOURCES

Beta Renewables website
http://www.betarenewables.com/; accessed October 2013.

Biochemtex website
http://www.biochemtex.com/index.html; accessed October 2013.

Biosphere website
http://www.biospheresrl.com/; accessed October 2013.

Brehmer, B. (2008). Chemical Biorefinery Perspectives: The valorisation of functionalised chemicals from biomass resources compared to the conventional fossil fuel production route. Ph.D. Thesis Wageningen University, the Netherlands. 181 pp.

Campbell, J. et al. (2013). Seasonal energy storage using bioenergy production from abandoned croplands. Environmental Research Letters, 8(3), p.035012. Available at: http://stacks.iop.org/1748-9326/8/i=3/a=035012?key=crossref.9b75538ad984ace4dfd9cbf5dec62d0e; accessed November 2013.

CIRI and CRPA (2011). Università di Bologna, Centro Ricerca Produzione Animale SpA, Aster Rete Alta Tecnologia Emilia-Romagna: “Proposta di metodo di analisi e valutazione di filiere di biomassa per la Regione Emilia-Romagna”.

Conserve Italia website http://www.conserveitalia.it/; accessed November 2013.

ENEA, (2009).“Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS” - Report RSE/2009/167.

ENI Versalis website http://www.eni.com/it_IT/azienda/attivita-strategie/petrolchimica/polimeri-europa/polimeri-europa.shtml; accessed October 2013.

Eurostat (2008). Nace Rev.2 - Statistical classification of economic activities in the European Community. 363 pp.

European Bioplastics website
http://en.european-bioplastics.org/bioplastics; accessed October 2013.

German Federal Government (2012). Biorefineries Roadmap as part of the German Federal Government action plans for the material and energetic utilization of renewable raw materials. 108 pp.

International Energy Agency, Bioenergy Task 42 (2012). Biobased Chemicals - Value Added Products from Biorefineries. 36 pp.

International Energy Agency, Bioenergy Task 42 - Biorefinery website: http://www.ieabioenergy.task42-biorefineries.com accessed October 2013.

ISTAT (2012), VI Censimento Agricoltura - Edizione Ottobre 2012.

Kamm, B.and P. Gruber (2006). Biorefineries - Industrial Processes and Products. M. Kamm (ed.). Weinheim: Wiley-VCH, 2006. ISBN-13 978-3-527-31027-2.

Matrica website http://www.matrica.it/; accessed November 2013.

Nowicki, P., M. Banse, C. Bolck, H. Bos, E. Scott (2008). Biobased economy: State-of-the-art assessment. 66 pp.

Osservatorio Agro-alimentare (2010). Il sistema agro-alimentare dell'Emilia-Romagna. Rapporto 2010. A cura di R. Fanfani e R.Pieri. Maggioli Editore. pp. 446.

Regione Emilia-Romagna, Regional Energy Planning website http://energia.regione.emilia-romagna.it/entra-in-regione/programmazione-regionale/piano-energetico-regionale ; accessed September 2013.

WEC (2010). The Future of Industrial Biorefineries, World Economic Forum.

Graphics **www.musicanti.eu**