BIOMASS KNOWLEDGE

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Introduction

Exploitation of this resource is not distributed homogeneously across the Planet. The vegetation that covers our planet is a natural storage of solar energy. The organic matter composing it is called biomass. Biomass is produced through the photosynthesis process, when carbon dioxide from the atmosphere combines with underground water to produce sugars, starch, cellulose, lignin, protein substances, fats, etc. The same solar energy that activated the photosynthesis is contained in the chemical bonds of these substances. In this way 2 x 10^{11} tons of carbon are fixed each year, with a corresponding energy content of 70 x 10^{3} megatons of oil.

What is it

The vegetation that covers our planet is a natural storage of solar energy. The organic matter composing it is called biomass. Biomass is produced through the photosynthesis process, when carbon dioxide from the atmosphere combines with underground water to produce sugars, starch, cellulose, lignin, protein substances, fats, etc. The same solar energy that activated the photosynthesis is contained in the chemical bonds of these substances. In this way 2 x 10^{11} tons of carbon are fixed each year, with a corresponding energy content of 70 x 10^{3} megatons of oil. By burning biomass, atmospheric oxygen combines with the carbon contained in the biomass, freeing carbon dioxide and water, and producing heat. Carbon dioxide goes back into the atmosphere and is ready to be re-used in the photosynthesis process to produce new biomass. Therefore, biomass is a renewable resource.

The term biomass indicates several types of products: agricultural and forest residues, waste of wood processing industry (wood shavings, sawdust, etc.), waste of the zoo-technical industry, agricultural and food residues (residues of crops for the production of human and animal food (straw), “energy cultures” aimed at the production of fuel, and organic biomass from other sources, such as the green fraction of solid urban waste and other types of heterogeneous industrial waste.

What is for?

In The main applications of biomass are energy production (biopower), fuel synthesis (biofuel) and product synthesis (bioproduct). In the energy field, wood and cellulose biomass (wood and by-products of grass, tree and forest cultivation) is mainly used as multi-purpose fuel: household heating, to produce electric energy and industrial uses. Other sectors affected by the processing of this raw material are the sectors of paper, cellulose, particle-board, compounds, animal food and chemical products. “Energy culture”, i.e. the cultivation of vegetal species growing rapidly, are generally used in the production of bio-fuels. For example, the processing of organic matter of plants producing vegetal oil and sugars (sunflower, sugar sorghum and beetroot) are the raw material of bio-ethanol, which can be used as an additive for petrol and bio-diesel, that is a mixture similar to

gas-oil. Bio-fuels, as well as producing heat and/or electric power, can be used as a car propeller, both mixed with other fuels or pure.

Where is it?

Biomass is one of the most abundant renewable energy sources on our planet. Its use, however, is not evenly spread. Bioenergy plays a role in all three main energy-use sectors: heat (and cooling), electricity and transport. Biomass in many forms - as solids, liquids or gases - can be burned directly to produce heat for cooking and heating in the residential sector by means of the traditional use of biomass or in modern appliances. It also can be used at a larger scale to heat larger institutional and commercial buildings, or in industry. The traditional use of biomass for heat involves primarily the use of simple and inefficient devices to burn woody biomass, in the form of fuelwood or charcoal, or agricultural residues and dung burned. Traditional biomass is mainly used in developing countries, where this energy source represents 34% - 40% of the total energy requirement. Modern bioenergy applications, on the other hand, are primarily used in developed countries, like Europe, Asia and North America.

A bit of history

Fire, unquestionably the most important discovery in the history of mankind, was discovered thanks to the accidental combustion of wood. Fire has illuminated, heated, protected and fed mankind for thousands of years. Briefly, fired fostered the birth of civilisation. Wood, on the other hand, remained the most widely used raw material for many centuries, not only to burn fires, but also as building material. The invention of the steam engine allowed mankind to obtain mechanic energy from the combustion of wood, whereas up to the 18th century wind and water where the only mechanic energy sources available, thanks to wind and water mills. During the Industrial Revolution wood started to become scarce owing to the massive deforestation carried out to produce energy. Mankind had to look for alternative energy sources and found them in coal and oil, which at the time were abundant albeit not renewable. Only recently, energy need and the possible disappearance of fossil fuels and the pollution produced by the combustion led man to “re-discover” the usefulness of wood and biomass as energy sources.

Biochemical processes

Biochemical processes work thanks to the action of fungi and bacteria that grow in the biomass in specific conditions of temperature and humidity. These micro-organisms digest organic matter freeing molecules that are waste (for them) but precious for us. Not all biomasses are suitable for these processes: fungi and bacteria do not eat absolutely everything but necessitate organic matter rich in proteins and water. Seaweeds, rejects from the cultivation of potatoes and beets, food waste and animal faeces are very good.

The main products that can be obtained with these methods are biogas, bioethanol, fertilizers for agriculture and heat. Biogas is a mixture of gases, predominantly methane (50-70%) and carbon

dioxide, which can be used for heating purposes or to make some particular plants allocated to the production of electrical energy work.
Bioethanol is an alcohol that can be used as car fuel. It is obtained from the fermentation of the sugars of beets and sugar cane. It is a fuel of great interest because it is clean and cheap. Another interesting application of biomass is for heating animal farms and cultivations. The decomposition of waste products, like leaves or animal faeces, produce heat that can be used to warm up greenhouses and stables.

Thermochemical processes

It is well known that to light and feed a fire you need materials that burn and these, in technical terms, are known as fuel. Fuel alone is not enough for a fire to burn; another element is required: the combustive agent. The most common combustive agent is oxygen, which, in a combustion reaction, has the task of "oxidizing" the fuel, with the consequent release of energy in the form of heat and light. Fire therefore is simply the visible manifestation of a chemical reaction, combustion, that takes place between two different substances: the fuel and the combustive agent. There are numerous combustible substances and materials. Initially man burnt wood, then coal. Today the most common fuels are the fossil fuels: petroleum, methane gas and coal or fossilized carbon. Combustion is the most ancient method to obtain energy from the biomass. Antique fireplaces, chimneys and stoves have now been replaced by modern and efficient heaters that are able to exploit the hidden energy of wood and its derivatives. Fungi and bacteria prefer humid protein substances, but fire feeds best on dry materials that are rich in cellulose. Cellulose is a complex molecule. It is very resistant and consists of long glucose chains, the simplest of sugars. Plants are made of cellulose, so are wood, leaves, paper and cotton. There are various systems to obtain energy from wood, that are classified according to the combustion temperature and the type of physical and chemical transformation that is obtained. Firstly, it must be pointed out that these systems use crushed wood. The chips of wood can be used just as they are or compacted in small blocks or pellets. Wood pellets increase the efficiency of the heaters and leave them cleaner. Wood transformed in this way can be burnt at extremely high temperatures (about 1000°C), and it turns into a mixture of gases that can move turbines and produce electric power. When it is burnt at lower temperatures, (from 400 to 800°C) wood separates into gases, liquids and solids. The solid component, coal, can still be used as a fuel, and the liquid component, pyrolysis oil can be used as a fuel for engines or can be used as the base in the synthesis of other products.

Biofuels

The word biofuel may refer to the fuels used for the production of electric energy, but in general it refers to liquid fuels used for means of transport. The most common fuels are undoubtedly bioethanol synthetized from carbohydrates and biodiesel (ester) obtained from fats and oils. Although ethanol obtained from starch and sugars, it offers a good contribution from the energy and environment point of view. Later we will examine ethanol produced from cellulose biomass like

herbaceous and wooden plants, agricultural and forest residues and large quantities of urban and industrial waste. In fact, while starch and sugars represent a modest quantity of plant material, cellulose and hemicellulose, which are polymers of sugar molecules, represent most of the biomass. The benefits connected to biofuels derive from the fact that they have a more limited environmental impact than oil derivatives and use waste materials that are usually not employed. Finally, other two biofuels will be analysed, that is methanol and corrected petrol compounds.

Bioethanol

Ethanol has always been used for internal combustion engines, as demonstrated by the history of cars. But, although the initial large availability and the low cost of hydrocarbons had not allowed to use them as fuels, after the oil shock of 1973 many other products were studied to replace car fuel (petrol and gas oil). Today, the product that shows a better compromise between price, availability and performance is ethanol. The synthesis of biomass ethanol is divided into four stages:

- production of biomass by fixing atmospheric CO_2 into organic carbon;
- conversion of biomass into a food that can be used for fermentation (usually as a sugar), by applying one of the many technological processes available: this conversion is what mainly differs with the various technological solutions for bioethanol conversion;
- fermentation of biomass intermediates by using bio-catalizers (micro-organisms like yeast and bacteria) in order to obtain a scarcely concentrated solution of ethanol. This stage can be considered as the oldest biotechnology ever developed by men;
- by processing the fermentation product the result is: combustible ethanol and by-products that can be used to produce other fuels, chemical compounds, heat and electric energy.

All these last processes, even though they are very different, conclude with the fermentation synthesis. The alcohol fermentation is a process that transforms the glucides contained in vegetal productions into ethanol.

Biodiesel

Recycled vegetal oils, animal fats and kitchen fats can be transformed into biodiesel by using a series of technologies in order to activate those chemical reactions, at low temperatures, that lead to the formation of compounds called esters. Esters can be liquid or solid; they are soluble in organic solvents and have a pleasant smell. Then they are transformed into biodiesel and glycerine. Glycerine is a secondary product that can be used for the production of hand creams, toothpaste and lubricants. Biodiesel can be directly used, since it does not require any type of intervention on the systems that apply it (motors and burners). It is used for motor propulsion (diesel engines) both as pure and mixed with the common gas oil and for heating. The use of biodiesel reduces the energy dependence on fossil fuels, the greenhouse gases emissions and health risks due to air pollution. It is not toxic and it is biodegradable within 30 days. Diesel mixed with biodiesel has a triple biodegradability.

Biodiesel contains traces of sulphur, that are in line with the new parameters established by EPA (Environmental Protection Agency) and that will be applied from the year 2006. It is safe to be

handled and transported: it can be stored in the same tanks as the diesel and pumped with the same equipment, except when it is cold (it is necessary to use tank heaters or shakers). It can be completely mixed with diesel and for this reason it is a very flexible additive.
Biodiesel, since it is an oxygenated product, helps to complete combustion. The reduction of polluting emissions is proportionate to its concentration in mixtures. One of biodiesel disadvantages is the emission of NOX: studies are being carried out to mitigate this problem. The performance of engines that use pure biodiesel, however, are 8-15% lower than traditional diesel, due to the different energy contents. In order to solve the above-mentioned problems, a 20% mixture of biesel and biodiesel is used. A mixture of biodiesel, ethanol (up to 15% in volume) and an additive (to help the two substances mix) is called e-diesel. The mixture is prepared by means of a spray-mixing, a process that does not require any particular equipment nor temperature control. E-diesel largely reduces the emission of particulates as compared to traditional diesel.

Bioproduct

Any compound that can be synthesised from fossil fuels can be similarly produced from biomass. These bioproducts (bioproducts) are therefore produced from renewable energy sources and usually their production needs less energy than their oil-based counterparts. Researchers demonstrated that the processes to produce biofuel can be combined to obtain antifreeze, plastic materials, glue, artificial sweeteners and toothpaste. Other reactants to obtain bioproducts are carbon monoxide and hydrogen. They form during biomass heating thanks to the presence of oxygen. This carbon monoxide-hydrogen mixture is known as biosynthesis gas, which gives life to plastic materials and acids that are essential for the production of photo films, textile and synthetic fibres. When the biomass is heated without oxygen being present, pyrolysis oil is formed, from which phenol can be extracted, i.e. an intermediate used for the production of wood sticks, plastic moulds and insulating foam.

Methanol

Also known as wood alcohol, methanol is usually produced from natural gas, but it can also be synthesised from biomass. The most common process is biomass gasification, that consists of vaporizing biomass at a high temperature, removing hot gas impurities and making it pass through a catalizer that converts it into methanol. Corrected petrol compounds deriving from biomass act as fuel additives in order to reduce the emission of pollutants.

The biomass dilemma

Today there is a growing interest in the use of biomass for producing biofuels, which can be used together with fossil fuels or can even replace them. However, there are some aspects that must be considered and that make the use of biomass on a vast scale controversial:

- to produce biofuels a large amount of energy is required. Energy is used to produce fertilisers, to plough fields, to harvest and transport biomass, to convert it into the final products and so on. This energy is usually obtained from fossil fuels: numerous researchers have calculated

that the energy put into the production of some biofuels is greater than the energy released when they are burned;

- the fossil fuel energy required for the cultivation and manufacture of biofuels releases carbon dioxide. Often the use of biofuels increases, rather than diminishes, carbon dioxide emissions: this is not only due to the aforementioned reason, but also to the clearing of forested land for the cultivation of energy crops, a phenomenon which is taking place in South America, for example;
- vast extensions of land and huge amounts of irrigation water are necessary to obtain large quantities of biofuels;
- extensive cultivation of energy crops can lead to the destruction of precious ecosystems, such as rain forests for example, which play an important role in maintaining the balance of the biosphere;
- in a world in which hundreds of millions of people suffer from hunger, the cultivation of products to be used as transportation fuel for other human beings is morally debatable.

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