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A Guide to Understand Biomass, Biofuel, and Biogas and to Enhance the Application in the Primary Energy Mix

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Abstract

The trends are changing in the energy markets and in the Governments vision to face new challenges. Traditional energies had to cope with new renewable energies, most of them intermittent and not dispatchable. Recently, bio energies arise from studies to implementation and doing their path. The present paper focus on the bio energies, their characteristics and how they can be used. It is planned to have a starting manual for new experts on these areas and their adjacent themes.

Keywords: Biomass; Biofuel; Biogas; Renewable Energy; Climate Change; Circular Economy

Abbreviations: CO_2: Carbon Dioxide; CH_4: Emission of Methane; DME: Dimitil Ether; MSW: Municipal Solid Waste; WWTP: Wastewater Treatment Plant; CHP: Combined Heat and Power

Introduction

Bioenergy is important for the whole world, as it is an alternative energy source, which generates few pollutants, less environmental risk and has a greater capacity for reuse. Bioenergy serves as a viable alternative to the use of fossil fuels and other energy sources potentially harmful to the environment. Its main function is to serve as a green and renewable source of energy. Bioenergy serves as a low-cost alternative, capable of being supplied not only by large producers, but also by small and regional ones. In its processing, bioenergy generates few GHGs, not contributing to the greenhouse effect.

Using bioenergy is a step beyond the world standard, which is based on the use of non-renewable energy sources. In this way, it is possible to impact agricultural industrial production and the environment in several ways. In addition, bioenergy depends on the use of waste from agricultural production itself, allowing the creation of a circular economy beneficial to small markets and producers. Several combinations of biomass source, process and technology are possible. The main processes for using biomass sources are:

- direct combustion (with or without physical drying, sorting, compression, cutting/breaking processes, etc.), usually in boilers or ovens. Although very practical and sometimes convenient, the direct combustion process is usually very inefficient. Another problem of direct combustion is moisture (20% or more in the case of firewood) and low energy density of fuel (firewood, straw, waste, etc.), which hinders its storage and transport.

- thermochemical processes: gasification (It is a process of conversion of solid fuels into gaseous, by means of thermochemical reactions, in which the resulting gas is a mixture of carbon monoxide, hydrogen, methane, carbon dioxide and nitrogen), pyrolysis (The process consists of heating the original material normally between and (e.g., firewood), in the "near-absence" of air, until the volatile material is removed. The main final product (coal) has an energy density twice that of the source and burning material at much higher temperatures), liquefaction and transesterification (a chemical process consisting of the reaction of vegetable oils with an active intermediate product (methoxide or ethoxide), derived from the reaction between

alcohols (methanol or ethanol) and a base (sodium or potassium hydroxide), where the products of this chemical reaction are glycerine, and a mixture of ethyl or methyl esters, biodiesel, followed by combustion in a machine, boiler or turbine; 300°C to 500°C;

- biological conversion, via bacterial anaerobic digestion (Occurs in the absence of air turning into a biogas rich in methane by the action of bacteria, acidogenic and methanogenic microorganisms) and fermentation (an anaerobic biological process in which plant sugars are converted into alcohol).

In general, materials with high moisture content, such as sugarcane, are more suitable for biochemical conversion and anaerobic digestion than for other forms of conversion. It is estimated that with the recovery of one third of the available waste, it would be possible to meet 10% of the world's electricity consumption and with a planting program of 100 million hectares of crops.

Agricultural waste, wood, sugarcane, eucalyptus, beetroot (from which alcohol is extracted), biogas (produced by the anaerobic biodegradation in waste and organic waste), firewood and charcoal, some vegetable oils (peanuts, soybeans, palm oil) are examples of biomass. At present, biomass is increasingly used in electricity generation, mainly in cogeneration systems and decentralized production. Municipal waste can be converted into fuel for transportation, industries and even homes.

Biomass resources are generally renewable, but only if the resource is harvested to the same extent as it grows, and soil nutrients are not depleted. Biomass cultivation absorbs as much carbon from the atmosphere as it is released into combustion or conversion into biofuels.

- Plants use the sun's energy in the photosynthesis process to form biomass and therefore store energy. Biomass can be used as food, raw material, fuel and heat or energy source

- Biomass is an indirect form of solar energy storage. Plants capture the sun's energy with an efficiency of about 0.1%, transform it into chemical energy and store it in its cellular structure (trunk, roots, leaves, etc.).

- Plants and trees absorb CO_2 from the atmosphere by storing it in its cellular structure. The burning of biomass returns stored CO_2 to the atmosphere. With the growth of new plants and trees this released CO_2 is again captured, thus maintaining the carbon cycle on the Planet

- If biomass is regenerated and collected for use, the cycle can be kept in equilibrium indefinitely and so that the carbon cycle is not changed.

- Bioenergy can be extracted from a variety of sources. These differ in their availability, combustion properties and uses. Biomass can be used to produce solid, liquid, and gaseous fuels.

Biomass includes wood, organic waste, manure, plants, and animal substances, among others.

Depending on its origin, biomass is classified as:

- Crops for energy purposes crops whose function is the storage of solar radiation in the form of biomass. Examples: rapeseed, sunflower, corn, etc.

- Forest and agricultural waste: the use of waste generated by cultivation activities or forestry activities, such as straw or wood waste, reduces the costs of the main products.

- Organic by-products: the processing of biomass for the creation of other products originates an additional group of by-products, such as organic waste, agricultural effluents, and industrial waste.

- Organic waste: this waste includes household waste and sludge from household and industrial effluents.

Biomass Recovery and Valorisation

In terms of sustainable forest management, it is important to collect and treat forest biomass, to analyze the technical resources and financial resources necessary to enhance their exploitation. In terms of energy recovery of biomass, the economic and social development of rural areas is envisaged, the implementation of cross-cutting measures that value forest-related activities, positively decrypting solid biofuels (firewood, shard, furry and forest waste) and the reference of a network of forest waste collection points that will then be routed to existing biomass plants or to the various industrial sectors of use of biomass. Figure 1 illustrates the changing paradigm related to using biomass as a primary energy. Biomass can be available in solid, liquid or gas forms. The way it is transported, stored, and used is different accordingly to the form it has at the moment.

Solid Biomass

Solid biomass includes all dry items from plants or parts of plants, wood waste, stem product residues and energy crops. It can be stored in the form of pellets or wood chips, for example. The use of solid biomass is of tremendous importance in the supply of energy worldwide; in developing countries, they predominantly use bioenergy for heating and cooking. In 2010, bioenergy was the most widespread form of renewable energy in the world, representing 9.5% of the world's primary energy. In 2012, the proportion of solid biomass (including waste) was about 9.7% of the world's primary energy.

The proportion of solid biomass (including coal) in the world's energy supply from renewable energy 68,9% in 2012. Because solid biomass is (theoretically) continuously available, it can be used to produce heat. Modern heating systems (ovens and boilers) use wood (in the form of firewood or splinters) and pellets. With or without electronic regulation, they can be equipped with firing

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systems that contribute to the combustion process free of harmful substances and with yields greater than 90%. For domestic heating, biomass in the form of pellets is increasingly used, requiring slightly more storage space than heating oil.

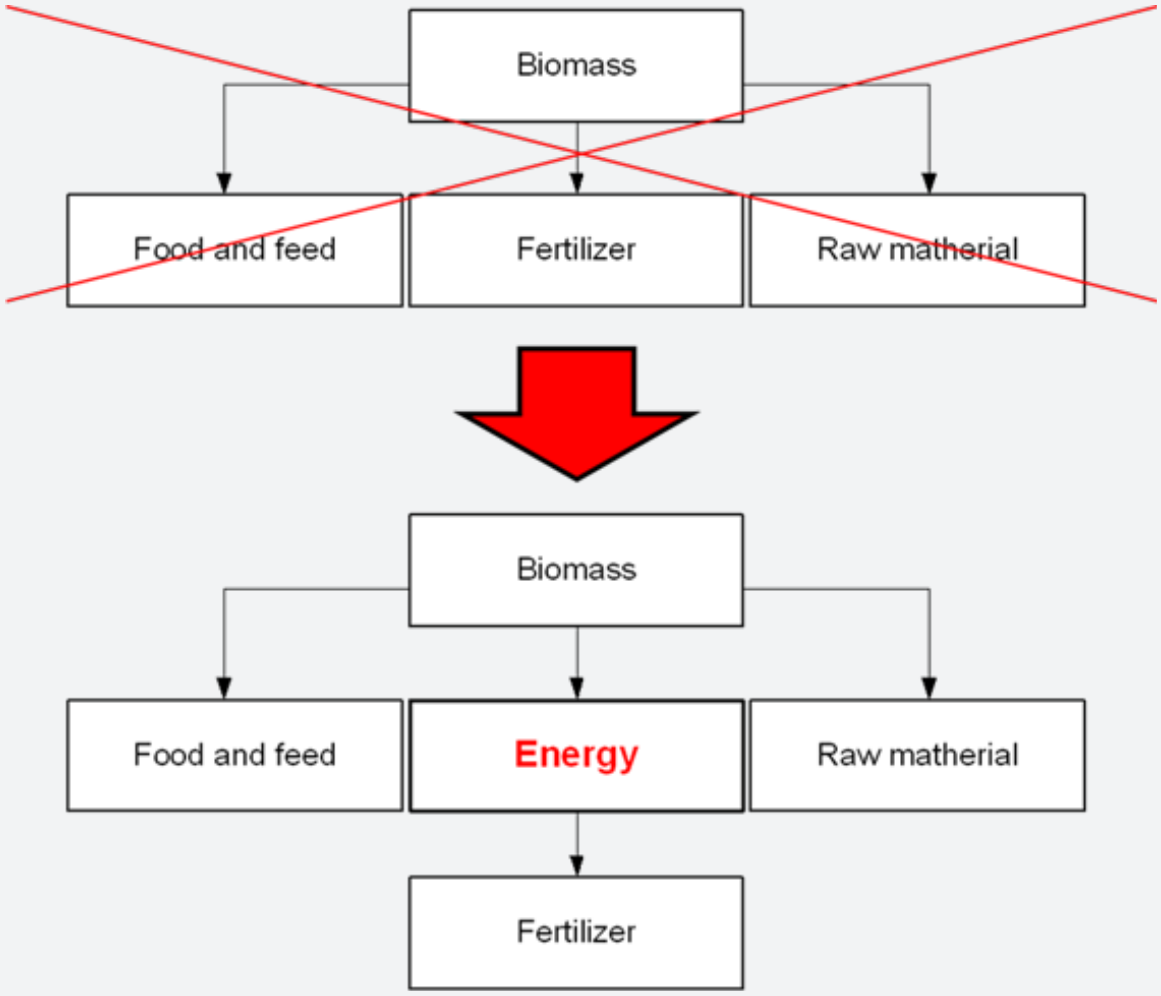

Figure 1: Energy opportunity in the biomass cycle.

They can also be used to produce electricity to compensate for fluctuations in wind and solar power. High-efficiency combustion engine systems or gas turbines are used. Total efficiency can be significantly improved using residual heat using CHP. Solid biomass is also used to generate electricity in heat and power plants (CHP). The waste heat produced by this electricity generation can be used in district heating networks or made available for industrial processes such as steam or heat. It can also be used to produce cooling for industrial purposes, for refrigerated warehouses or for air conditioning of buildings.

Liquid biofuels are obtained from solid biomass and are comparable in quality to conventional fuels. The two main biofuels are biodiesel and bioethanol, which represent 80% and 20% respectively of the biofuel market. There is also vegetable oil and synthetic biofuels.

Biodiesel

Biodiesel is produced from vegetable oils such as rapeseed or sunflower oil. Esterification provides the oil with better physical properties to make it more like conventional diesel. Mixed with conventional diesel, biodiesel is currently one of the most effective ways to rapidly reduce greenhouse gas emissions in the transport sector. Biodiesel has the advantage of being used in current diesel engines without special changes when mixed with conventional diesel and can be distributed using existing infrastructure. Biodiesel has the disadvantage of having to make some investments, since biodiesel has weaker storage properties than conventional diesel. In addition, it requires the addition of significant amounts of fossil energy.

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Synthetic Diesel

Synthetic diesel is a mixture of hydrocarbons chemically produced through an artificial process. The production method is based on the gasification of renewable biomass or biogas. Even if natural fossil gases were used as a base, synthetic diesel is much less polluting than normal diesel. The fuel can be mixed freely with normal diesel and can therefore be used in diesel-powered vehicles without the engines needing to undergo any change. Handling and distribution may take place in existing infrastructures. It has the advantages of having and very reduced emissions of carbon dioxide throughout the value chain and the power to be mixed with conventional diesel without causing any kind of problems. It has the advantages of possessing r a lower efficiency rate than fuels such as DME, methanol and biogas. Investment costs for your production are high, which may result in high costs such as fuel.

Methanol/Ethanol

Ethanol is produced through the fermentation of crops rich in sugar and starch, being considered the fuel with the greatest potential in the short term. Methanol is extracted through the catalysing of synthetic gas, which is filtered through distillation. Both ethanol and methanol can be mixed with gasoline in various proportions and have the same energy content. Vit was found that methanol produced from forest waste is the main candidate for the replacement of gasoline. It also has long-term advantages, as it can function without any modifications. However, it has the disadvantage of being harmful to human health and must be handled in fully sealed systems and that their cultivation and production use renewable energy sources so that ethanol is not harmful to the environment.

Biogas

It is considered a biofuel from a renewable energy source and was discovered in 1667. Biogas production occurs naturally in any submerged place where oxygen cannot penetrate, such as in swamps, at the bottom of water wells, intestine of animals. Biogas can be produced anthropogenically by biomass gasification by a thermochemical process in landfills and biogas plants. The fermentation process of the organic substance in the absence of air involves various anaerobic bacteria, the composition of which depends on the materials of organic origin and the specific processing conditions, such as temperature and pH value.

Biogas can be extracted from a variety of sources: from organic waste from landfills (landfill gas), from wastewater (sewage gas), from organic waste from industry, households and trade and organic waste from agriculture, forest, and energy crops. The fermentation residue of biogas production can be used in agriculture as fertilizer or sold as a by-product to increase the value creation chain. Of increasing importance is the processing of biogas with good quality that can be added to the existing natural gas network or be used as a fuel in transportation.

In general, biogas agricultural plants use liquid manure and energy crops as a fermentation substrate. Using liquid manure, energy in biogas plants decreases methane emissions from open liquid manure tanks. To increase gas production, more renewable sources such as corn, cereal crops, and many other energy crops such as sunflowers, Sudan grass, sugar beet, fodder radishes, sweet sorrh, etc. are being used (although it creates a food market conflict with energy market). The fermentation residue can be used in agriculture as a high-quality fertilizer, thus closing nutrient cycle in the cultivation of energy crops.

The resulting fermentation process is a biofertilizer (organic fertilizer and liquid effluent) that can be applied in agriculture without problems of contamination of groundwater and with the advantage of water containing nutrients such as nitrogen, phosphorus, and potassium. Biogas has its limited use in power generation due mainly to the presence of hydrogen sulphide (H_2S). Currently, most of the techniques used in the removal of H_2S from biogas are chemically based, having high material costs, and generating secondary pollutants. The biological removal processes of H2S have become an effective and economical alternative to traditional gas treatment systems based on physical-chemical techniques.

Biogas consists of methane that is extracted from biodegradable material or obtained through biomass gasification. It has a very small environmental impact and offers considerable future potential. It is possible to produce biogas to serve as fuel from waste from the food industry or selected household waste, and biomass gasification can also be used. Greenhouse gas emissions are greatly reduced throughout the production chain, particularly if the production method used is biomass gasification. It pollutes less than fossil fuels. This type of gas mainly reduces the emission of methane (CH_4) and carbon dioxide (CO_2).

- The use of biogas instead of firewood contributes to the fight against deforestation.
- Reduces water pollution.
- Allows the obtaining of carbon credits.
- It is a natural process to treat organic waste.
- In rural areas, the arrival of biogas may replace the use of firewood for coercion and complement the diesel of tractors.
- The use of biodigesters to collect human and animal waste can help (or even solve) public health problems resulting from waste loaded from microorganisms.
- Reduces unpleasant odours from garbage.
- Produces good quality fuel.
- Diversifies endogenous energy sources.
- Increases opportunities in the labour market.
- Allows the creation of an income generation scheme.

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- It produces a fertilizer rich in nutrients as waste.

Biogas requires substantial, costly, and complicated vehicle modifications and costly investments in new infrastructure.

Biogas Added with Biodiesel

Biogas and biodiesel can be combined with separate deposits and injection systems. To achieve compression-ignition of the diesel engine, biogas is mixed with about 10% biodiesel or synthetic diesel. Thus, **it**is necessary to control combustion in a diesel engine without reducing the power of the engine. The efficiency tax is higher and there is greater reliability of operation than a gas vehicle with a mixture of 90% biogas. However, biogas in its liquid form is about 25% more expensive than compressed biogas. Investments in infrastructure are needed for both biogas and biodiesel due to their reduced stability during storage.

Dme (Dimethyl Ether)

DME (dimitil ether) is a gaseous fuel that can be produced from natural gas and biomass. As fuel for vehicles, the DME is handled in its liquid form under low pressure, which requires a single and advanced fuel system. Among other things, a special fuel pump and injectors and a larger (heavier) tank that can withstand higher pressure are required. The MSD requires, in the short term, investments in infrastructure like those already existing, on a smaller scale, for the GPL. DME is considered a very interesting long-term alternative, mainly due to its extremely low environmental impact.

Hydrogen Added with Biogas

Hydrogen is not an energy source in the conventional sense of the term, but rather an energy conductor, such as electricity. It can be produced by gasification of biomass or electrolysis of water, i.e., dividing it into hydrogen and oxygen with the help of electric current. It has the advantages of having a lower environmental impact and be of considerable interest as a future means for fuel cells. As a disadvantage, and ste fuel is only suitable for a limited number of applications and requires costly modifications to vehicles, including a complete tank system, which will result in high costs and a higher weight. Hydrogen infrastructure sits the most expensive and the most complex of all the alternatives presented, as hydrogen requires higher pressure than biogas.

Municipal Solid Waste (MSW)

Household waste can be an alternative energy source to fossil fuels, giving rise to electricity and thermal energy, with significant impact in reducing CO2 emissions. It is also an example of a circular economy: yesterday's waste is now becoming a resource with economic and social value. Cities are now encouraged to treat their waste more sustainably. The regulation limits the volume of waste to be landfilled, with energy recovery being a growing solution. Figure 2 illustrates the cycle from waste to energy. WWTP stands for wastewater treatment plant and CHP stands for Combined Heat and Power.

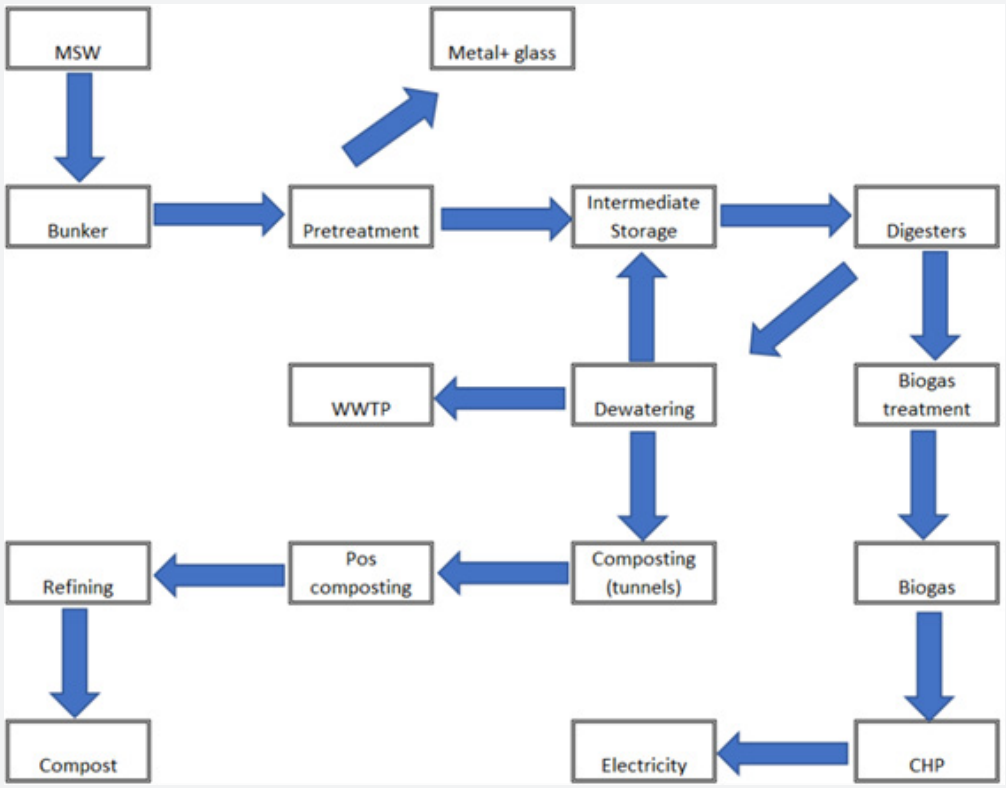

Figure 2: Full waste to energy cycle in MSW plants.

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Energy recovery is a controlled and automated process that simultaneously treats thermally undifferentiated waste, additionally enabling the production of electricity through the steam generated by combustion.

- The heat generated during the incineration process is recovered in the form of steam - thermal energy - which can then be.
- used directly to provide municipal heating networks.
- injected into the turbo-group, which transforms thermal energy into electric energy, which can be sold to distributors.

Energy Recovery of Forest Biomass in Portugal

In Portugal, the forest occupies about 38% of the territory, and it is necessary to plan to ensure the disposal of waste from its biomass (branches, pecking, pinecones, etc.) from pruning, pruning, cleaning, felling of trees and other forestry operations. Until a few years ago, forest biomass was used differently from what is used today. One of its uses was as food essentially for sheep, goats, and cattle. It also served to put in the stable, capoeira or scythe as a 'bed' for animals and then served as manure or manure (together with the faeces of the animals) to compost the agricultural fields. Some of the biomass (such as carqueja, caruma, miscellaneous foliage and pinecones) was also used in the fireplace to light the fire that served to cook, for stills, to heat the house or to smoke sausages.

The rest, which was in the hills and forests, would serve as humus and for temporary shelter for some animals. More recently, forest biomass has begun to be used for cogeneration to produce electricity in thermal power plants and to produce heat in the industry. There are two ways to produce heat: by direct combustion and indirect combustion. In direct combustion, forest biomass is added to fossil fuels (such as fuel oil and coal) and then burned. In indirect combustion, forest biomass is deposited in a landfill (together with other waste) and methane gas from its decomposition is burned. In this second process, waste can then be used for fertilization of land and soil.

For the national forest component, it originates from olive, eucalyptus, rose and holm oak and it is estimated that its annual production is six million tons, but the volume available in the forest is two million tons, which add 200 thousand from the wood processing industry. Thus, the biomass row should be seen as a strategic area not only to reduce the risk of fire but also in its use for energy purposes. Forest biomass is not used to produce biofuels to supply cars. Biomass for this purpose is of agricultural origin, such as sunflower, rapeseed, beetroot, corn, and turnip.

This use has great disadvantages. One of them is on farm, that is, large-scale production, in which agricultural and forestry land is used, will reduce food products produced and reduce forests. Another is its marketing, in which producers make more money by selling the products to fuel companies than to supermarkets. This leads to these foods being more expensive, because their supply is smaller, and will create hunger problems in the poorest families. Therefore, it is customary to hear that these fuels are not sustainable, but that second-generation fuels are already.

The process of energy use, first involves the collection of the various wastes of which it is composed, followed by transport to the places of consumption, where direct combustion is made by replacing the use of fossil fuels. The forestry industries have been using biomass to produce thermal and electric energy for about 30 years. The energy ratio is 1ton (ton) wood is equivalent to 0.359tep (equivalent ton of oil) for conifers or 0,331tep for hardwoods. The calorific value of biomass produced annually in Portugal is about 2 million tep [1]. In Portugal, there are nine biomass thermal power plants for heat cogeneration in various forest-related industries.

There are only two biomass thermal power plants for energy production. The largest, with 9 MW, is located in Montague. Providing 60GWh of electricity per year (sufficient for a population of 35 thousand), the Bioelectrical unit (part of EDP) consumes about 80ktons of forest waste per year. The second, with only 3,5MW, in Vila Vela do Ródão, spends about 40ktons. It is planned by the end of this year of exploration of two new forest biomass plants. The tenders for the allocation of power to forest biomass thermoelectric plants aim at the installation of 15 new thermal power plants located in regions of the country with high risk of fire and abundance of forest waste, with a total of 100 MW of installed power. The Government's objective is to guarantee by 2010 a 150 MW power allocated to biomass plants as a contribution to achieving the European commitment to guarantee 22.1% of national electricity consumption from renewable energy sources by 22,1%. On the other hand, it is intended to reduce greenhouse gas emissions. The third objective is to reduce the risk of fire, making the area annually covered by forest fires is less than 50kh [2-3].

Figure 3 illustrates the location map of the thermal power plants in Portugal [4]. The advantages of this recovery are the use of a renewable resource, the low cost, no sulphur dioxide emissions, significant reduction of global carbon dioxide (CO_2) emissions into the atmosphere, ash is less aggressive to the environment than those from fossil fuels, less corrosion of equipment (boilers, ovens, etc.), lower environmental risk and reduction of fire risk (by encouraging the cleaning of forests).

The disadvantages are the lower calorific value of biomass, difficulties in stock and storage and risk of over exploitation of the forest. Bioenergy can be converted into:

- Calorific Energy: produced in combustion systems. On a small-scale heat can be used to heat a dwelling (fireplaces, salamanders, etc.) and on a large scale to produce heat in plants that, through thermal networks, distribute heat to various dwellings.

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- Mechanical energy: produced by means of heat and energy generators, such as steam engines or internal combustion engines. The heat produced by this process must be dissipated into the environment through a cooling system (biodiesel or ethanol in the transport sector).

Electric Energy: systems that produce mechanical energy, in combustion engines or in direct and indirect combustion turbines, coupled to electric generators. They convert mechanical energy into electrical energy.

Figure 4 illustrates the Bioenergy plant generic stages. Advantages of bioenergy:

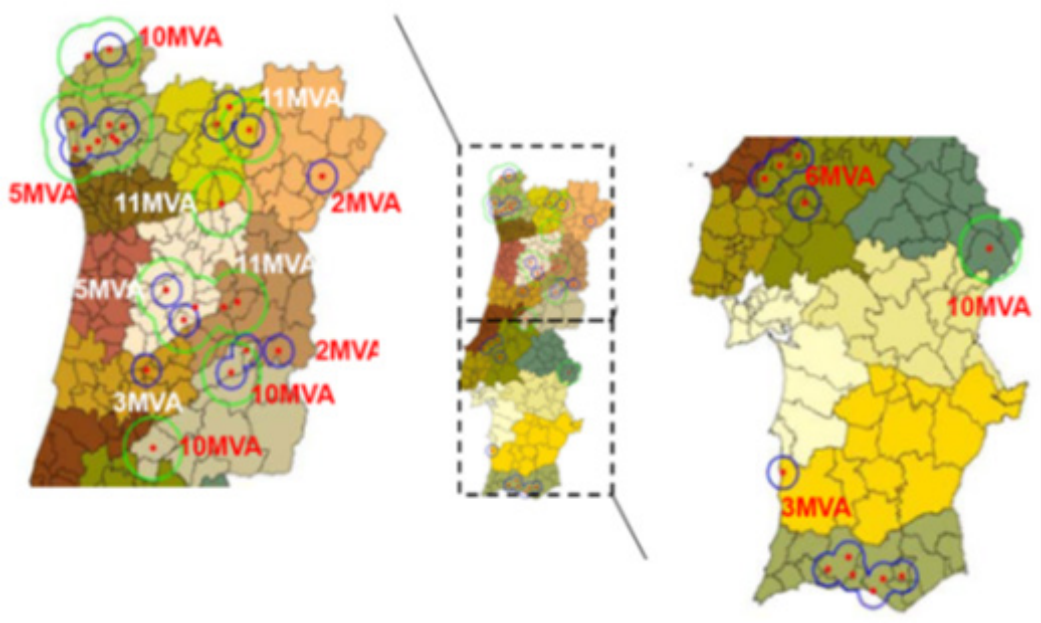

Figure 3: Location of the thermal power plants in Portugal.

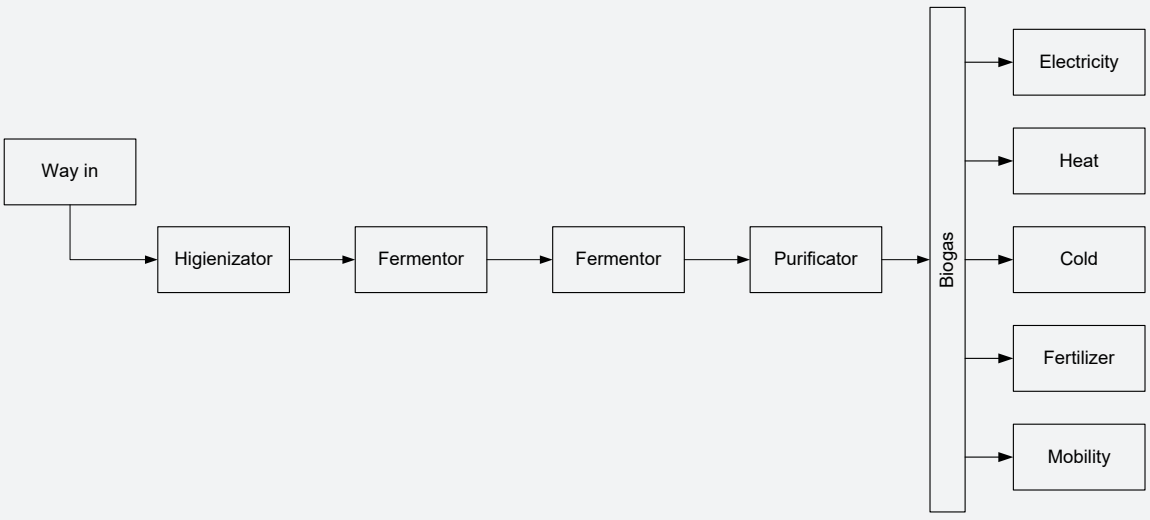

Figure 4: Bioenergy plant generic stages.

- Bioenergy is virtually CO_2 neutral. It just gives the amount of carbon dioxide that plants absorbed earlier when they were growing. In terms of CO_2, it is irrelevant whether wood deteriorates in the forest or is used to produce energy.
- Biomass is storable and flexible in use.

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- Biomass can balance fluctuations in solar and wind energy by virtue of its flexibility and constant availability.
- Biomass is available in almost all countries.
- The use of biomass helps reduce waste disposal problems, while at the same time providing valuable energy.
- Agricultural regions benefit from the creation and safeguarding of jobs in agriculture and forestry, as well as throughout the production process.
- The planting of energy crops opens new business opportunities for farmers.
- The use of bioenergy decentralizes energy production and creates a material and energy cycle.
- Bioenergy in solid, liquid, or gaseous form is used to generate electricity/heat and manufacture biofuels. An important benefit of bioenergy is that it can be stored.
- The stationary use of biogas in combined heat and energy plants for energy and heat production (CHP) increases efficiency. The electricity produced can power the public grid or be used as an independent power source for commercial, rural, and isolated network facilities. Waste heat can be used in downstream systems for additional power generation, but also for use in heating, drying, machine cooling operation and process heat.
- Another attractive option is to add biogas to the natural gas network. After refining it to obtain the quality of natural gas (obtaining biomethane with a methane content up to 98%), biogas can be used in areas with high heat consumption.
- In energy networks where production follows consumption, biogas plays an important role in the electricity grid as a long-term energy storage facility, thus helping to bridge seasonal fluctuations in electricity supply from solar and wind power plants.
- In energy networks where production follows consumption, biogas plays an important role in the natural gas network as a reduction in the amount of supply on the rise, thus helping to reduce the need to strengthen supply.

Its legal framework is as follows [5]:

- Decree-Law No. 62/2006 of 21 March transposes Directive No 2003/30/EC into the national legal order and establishes mechanisms to promote the placing on the market of minimum biofuel quotas in place of fossil fuels, with the aim of contributing to security of supply and the fulfilment of national climate change commitments.
- Decree-Law No. 66/2006 of 22 March establishes the creation of a tax incentive (reduction/exemption of ISP).
- Ordinance No. 3-A/2007 of January 2 establishes the value of the EXEMPTION of the ISP for biofuels until December 31, 2007, and in the case of small producers dedicated that period extends until December 31, 2010.

The remuneration is that provided for in DL No. 225/2007, with Indicative Average Rates for forest biomass being 102-104 (€/MWh) during the first 25 years.

Fiscal and legislative framework in Portugal

Directive 2001/77/EC of 27 September 2001: Biomass: the biodegradable fraction of agricultural products and waste (including plant and animal substances), forest and related industries, as well as the biodegradable fraction of industrial and urban waste.

DIRECTIVE 2009/28/EC of the European Parliament and The Council: Biomass: Biodegradable fraction of organic products, waste and waste from agriculture, forestry and related industries, including fishing and aquaculture, as well as the biodegradable fraction of industrial and urban waste; Bioliquids: Liquid fuels for energy purposes, other than those intended for transport, including electricity, heating and cooling, produced from biomass; Biofuels: Liquid or gaseous fuels for transport, produced from biomass.

TdB- biofuel bonds are excise duties. Under the legislation regulating excise duties ("IEC") at EU and national level, the production, processing, holding or storage and movement of products subject to IEC under tax suspension (i.e., without payment being made) are subject to tight control rules and can only be carried out in certain locations and under certain conditions. Operators involved in these transactions are obliged to obtain specially provided for statutes (authorised depositary or registered operator), recognised by the customs/tax authorities of the Member States, subject to their tax suitability and, in certain cases, a certain economic/financial capacity and provision of guarantees.

Once these statutes are recognised, operators shall be subject to a wide range of obligations, in particular as to the accounting record of product movements and to checks of the competent authorities. In the case of biofuels and their incorporation into diesel/petrol, such mixing operation, if the products are not under tax suspension and have been regularly introduced for consumption and the taxes due in Portugal are paid, there is no obligation to set up a tax warehouse (and obtain authorized depositary status). The movements (movement) of products subject to IEC under a tax suspension regime are subject to computerised procedures, recorded in a computerised system that operates throughout the EU, from the dispatch of products to the confirmation of their receipt at destination, covered, as a rule, by guarantees to safeguard the risks of irregularities and debt formation. Thus, the risks of irregularities are minimised and, if they occur, the risks of non-collection of taxes due, in view of the existence of a guarantee, will be greatly reduced.

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As for products already introduced for consumption in other Member States, a guaranteed mechanism is provided for at destination prior to the dispatch of the products, which aims to ensure the payment of the tax, and declarative procedures are also put in place to allow the control of movement. The level of incorporation of biofuels does not change tax taxation in terms of ISP, in accordance with article 92(9) of the CIEC. From the analysis of the evolution of the issues in consumption declared to the TA for diesel and gasoline, in the period 2015-2017, it is not possible to identify significant changes in the indication for an increase in irregular/fraudulent introductions to consumption, not even in the face of the most significant increase in taxation in the years 2015 and 2016 (with the creation of the "carbon tax" and the increase in ISP rates).

From the contributions submitted and hearings made to industry associations it can be concluded that the CSIs scheme works well and that it is considered, in some respects, as a model to be followed under the legislation governing biofuels. It is therefore not the basis for considering the high values that have been advanced by some of these associations for the media in terms of loss of tax revenue over the last few years. It is also possible to conclude that in many situations irregularities in fuels purchased in other countries (maxime Spain) are based on non-compliance with the percentages of biofuel incorporation, and do not extend to non-compliance with tax obligations. Without prejudice to Portugal's obligations under the EU Treaties and on the functioning of the EU, on the freedom of movement of goods, and which make systematic checks at the land border impossible for goods originating in other Member States or which are for free circulation, it is considered appropriate to recommend the intensification of surveillance, joint actions between the competent authorities.

The current sanctioning framework for tax violations is appropriate and has not been criticized or suggested to change or improve by industry associations. The number of TdBs issued has been gradually and consistently increasing between 2013 and 2017, an average of about 12.4% per year, and the issuance of securities associated with biofuel production has directly accompanied this evolution. Although there was a large volume of imports in 2015 and 2016, in 2017 the values again reduced to a value in line with that observed in 2013. In relation to the consumption of TdBs, between 2013 and 2017, there was also growth. However, the annual deficit of TdBs of non-compliant operators has consistently increased significantly. This situation, which has remained irregular because inherent compensation has not been paid by the operators concerned, is necessarily correlated with the significant increase in fuel issues by these operators, which (i) or do not have incorporated biofuels, or (ii) those which have are not recognised as sustainable by the ECS, not be accompanied by the documentation required for its issue.

The volume of introductions to consumption between 2012 and 2017 increased on average 1.2% per year in diesel but decreased on average 1.3% per year in gasoline. Thus, overall, introductions to consumption increased by an average of 0.8% per year in the period under analysis.

Between 2012 and 2017, the top 5 operators increased their introductions to diesel consumption by an average of 0.8% per year in diesel but reduced on average 1,9% per year in gasoline. However, non-compliant operators significantly increased their introductions by volume on average by about 39% in diesel and 68,6% in petrol in the same period respectively. It can be seen that non-compliant operators, despite still having a reduced share of consumption when compared to the top 5 operators, have a much more relevant position in imports and grew significantly between 2016 and 2017. All imports reported by non-compliant operators to ENMC originated in Spain and the vast majority originated in CLECs warehouses. Imports by non-compliant operators were always identical to the volume of diesel and petrol they introduced to consumption each year.

According to DGEG data, the volume of sales of diesel and gasoline decreased by an average of 1,9% per year between 2012 and 2017, with a higher incidence in gasoline (4,1% on average decrease) vs. diesel (1,4% on average decrease). Nevertheless, there was growth in 2017 of about 1,4%. In 2017, the lowest level of biofuel volume incorporations was reached in the period under review, where there was a negative value between the TdBs issued in the year and those that would be necessary to comply with the environmental obligations of that year. Imports by non-compliant operators, because they do not include biofuels and in cases where they have them, are certainly not recognised as sustainable, certainly contribute to this situation.

In 2017, the prices of brands associated with non-compliant operators were below those practiced by the four main brands operating in the market. It has been found that one of the non-compliant operator's practices price levels very aligned with hypermarkets and sometimes even below them. It is clear that operators who do not meet the biofuel incorporation targets open up an undue competitive advantage that allows them to practice lower prices, without prejudice to the importance of recognising that the differences between the lowest and highest prices result from operating models and cost structures that are not directly comparable.

However, this advantage which misdirects competition in a market that is desired free and competitive is also found in wholesale trade, where, in theory, they seem to make the greatest of their introductions to consumption. In the present study, three potential risks associated with the irregular entry of road fuels into national territory were identified and analysed, namely i) Transport and sale of undeclared fuel in Portugal, which entered via land border, ii) Transport and sale of undeclared fuel to ENMC

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(i.e., only declared to TA) and iii) Obtaining TdBs improperly to ensure compliance with the incorporation targets.

The emission of TdBs can be carried out in three ways: the production of biofuels - The producer reports monthly to the LNEG the production of biofuels, providing the characterization of the respective process: raw materials, origin, reduction of GHG emissions, etc., which in turn issues the corresponding TdBs; o Acquisition of biofuels outside Portugal - Obliged operators 7 report to LNEG monthly biofuel (pure or incorporated) providing all the necessary documentation to prove the sustainability, quantity and quality of them (namely PoS, Transport Guide, among others), which in turn issues the TdB corresponding to this renewable fraction; Production of biofuels by small producers dedicated ("PPD") for dedicated fleets (adapted vehicles) - These "TdBs" are available for sale by auction by DGEG, where obliged operators can purchase them.

After a period in which regimes of total and partial exemption of ISP for biofuels, pure or incorporated in gasoline or diesel, under the (then in force) Excise Code, approved by Decree-Law No. 566/99 of December 22, have been in force in Portugal, in the wording given Decree-Law No. 66/2006, of March 22, which enlisted to this diploma Article 71a, these exemptions would be eliminated, remaining in the current wording of the CIEC, approved by Decree-Law No. 73/2010, of June 21, only the exemption for small producers dedicated, in Article 90. These EXEMPTIONS of ISP had also associated with the exemption from the Road Service Contribution (CSR), created by Law No. 55/2007 of 31 August (Regulates the financing of the national road network in charge of ep - Estradas de Portugal, E. P. E.), which only focuses on road diesel and gasoline (and, more recently, also on the auto GPL), subject to and non-exempt ISP.

Biofuels are now subject to ISP in accordance with Article 88(2) (h) of the CIEC and are subject to the level of taxation applicable to the product they are intended to replace, in accordance with Article 92(9) of the Same Code: "Any product used as a fuel is subject to the level of taxation applicable to the replaced fuel oil and energy product". The "level of taxation" is defined in Article 88(5) OF the CIEC: "For the purposes of the tax on petroleum and energy products, the total amount of the ISP and other taxes collected, excluding VAT, calculated directly or indirectly on the basis of the quantity of petroleum and energy products at the time of their introduction into consumption shall be considered." This rule of taxation of biofuels in accordance with the substituted product is rooted in Article 2(3) of Directive 2003/96/EC, which, notwithstanding the minimum levels of taxation for biofuels, provides, for petroleum and energy products intended for use as fuel or fuel, the rule of taxation according to the substituted product (equivalent).

Road diesel and gasoline are taxed, in ISP, in accordance with Article 92 CIEC, with fees to be defined by Ordinance of members of the Government, within the range set in this CIEC standard. Under Ordinance No. 385-I/2017 of December 29, these fees are currently €343.15/1000l (for road diesel) and €556.64/1000l (for petrol). In addition, the CSR, already mentioned above, created by Law No. 55/2007, which constitutes the consideration for the use of the national road network, as it is verified by the consumption of fuels, and which is currently set at €111/1000l in the case of road diesel, and € 87/1000l, for petrol, provided that it is subject to ISP and not exempt (wording given by Law No 82-B/2014, December 31). In addition, the addition on CO2 emissions (commonly referred to as the "carbon tax"), provided for in Article 92a of the CIEC, a standard that was added to the CIEC by Law No 82-D/2014 of 31 December (Changes environmental tax standards in the energy and emissions, transport, water, waste, land-planning, biodiversity, while introducing a plastic bag taxation scheme and an incentive scheme for the slaughter of end-of-life vehicles in the framework of an environmental tax reform).

The applicable rate to be in force for the year 2018 was set by Ordinance No. 348/2017 of 28 December, at €16.95/1000l for diesel, and €15.56/1000l for gasoline. In total, the level of taxation of road diesel in Portugal amounts to €471.10 / 1000L, and, in the case of petrol, this level of taxation is € 659.20/1000L.26 The addition on CO2 emissions only relates to the products specially identified in the table provided for in Article 92a of the CIEC, since this imposition and the factor of the addition provided for therein are directly related to the level and emissions of CO_2 associated with each of these products. Pure biofuels, i.e., when not incorporated, are not subject to the addition. In the case of biofuels incorporated in road diesel, taxation is affected on the final product obtained with the mixture (incorporation): i.e., the final product is taxed as road diesel in ISP, CSR, and addition on CO_2 emissions. And the level of taxation is the same, regardless of the amount (%) of biofuel incorporated: taxation will be that of the final product (road oil/petrol).

As for the incorporation operations themselves, in accordance with Article 7(2) of the CIEC, the operations of incorporation or mixture of biofuels into diesel/petrol are subsumable in the concept of 'production', as mentioned above. As such, and regarding the incorporation of biofuels produced and which are in tax suspension, it is mandatory to set up a processing tax warehouse, as is apparent from the combination between the arts. 21st and 97th CIEC. In the case of products already introduced for consumption in Portugal (i.e., which are not under a tax suspension regime), including, in this case, biofuels for incorporation, it is not apparent from tax legislation any obligation to set up and tax warehouse for the purpose of carrying out mergers.

Moreover, and as has already been mentioned above, Article 96 (paragraphs 2(c) and 3 of the CIEC) provides that 'production of petroleum and energy products' is not considered the operation of mixing, outside a production establishment or customs warehouse, of petroleum and energy products with other

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petroleum and energy products or other substances, provided that the basic substance tax has been paid previously (i.e. paid in Portugal) and the amount paid is not less than the amount of tax due for that mixture. On the other hand, the legislation governing the subject of biofuels, decree-law no. 117/2010, no longer provided, in the wording given by Decree-Law No. 152-C/2017 of December 11, the obligation and constitution and tax warehouse for these purposes, maintaining only the obligation to create a processing tax warehouse for small, dedicated producers wishing to benefit from the exemption provided for in Article 90 of the CIEC (arts. 19 of Decree-Law No. 117/2010, in conjunction with Article 96(3) of the CIEC and Article 97 of the CIEC).

Conclusions

Bioenergy serves as a low-cost alternative, capable of being supplied not only by large producers, but also by small and regional ones. In its processing, bioenergy generates few GHGs, not contributing to the greenhouse effect. Using bioenergy is a step beyond the world standard, which is based on the use of non-renewable energy sources. In this way, it is possible to impact agricultural industrial production and the environment in several ways. In addition, bioenergy depends on the use of waste from agricultural production itself, allowing the creation of a circular economy beneficial to small markets and producers.

About tax legislation, or with tax relevance, there is nothing to prevent the execution of mixing/incorporating operations in accordance with the applicable legislation, biofuels, and diesel/petrol, regularly introduced for consumption, outside of tax warehouse, provided that, it is proven, that the conditions laid down on legislation bare shown to be observed, the payment of taxes due for their introduction into consumption.

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