ENERGY FROM BIOMASS

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Introduction

The technologies used to obtain energy (biopower) from different types of biomass are different and the resulting energy products are different too. Biopower technologies convert renewable fuels of biomass into heat and electricity by using equipment, which is similar to the one used for fossil fuels. An advantageous characteristic of biomass is its availability, as it is able to keep its energy intact until it is used.

Energy production

Thermo-chemical conversion processes of biomass are based on the action of heat that activates the chemical reactions needed to transform the matter into energy and can be used for those cellulose and wood residues whose C/N ratio is over 30 and the humidity content is lower than 30%.
The biomass that is more suitable to be subject to thermo-chemical conversion are wood and all its derivates (sawdust, wood shavings, etc.), the most common wood-cellulose by-products (cereal straw, grapevine pruning residues, fruit trees pruning residues, etc.) and some processing waste (husks, chaff, stones, etc.).
Bio-chemical processes: bio-chemical conversion processes allow to obtain energy throughout a chemical reaction that takes place thanks to the contribution of enzymes, mushrooms and micro-organisms, that form in the biomass under particular conditions, and are used for that biomass whose carbon/nitrogen ratio is lower than 30 and humidity at collection is higher than 30%. The following products are appropriate for chemical conversion: aquatic breeding, some cultivation by-products (leaves, sugar-beet stems, vegetables, potatoes, etc.), liquid residues of zoo-technical industry and some processing waste (residues of alcohol processing made of grains, vegetation water, etc.), and some types of urban and industrial waste water. The technologies that are currently used in the biopower sector are: cofiring, pyrolisis, gasification, combustion, "small modular" systems, aerobic digestion, anaerobic digestion, and carbonization.

Gasification

At present, in terms of biomass, "gasification", which is a thermo-chemical process, is considered as one of the best and most promising technologies to produce electric energy: both as far as efficiency and environmental impact are concerned. Each plant is subdivided into three sections, where three stages of the productive process are carried out: gasification, gas turbine and thermal cycle. During gasification, the wet biomass is conveyed into a drier making excess water evaporate. After being dried, biomass proceeds to the gasifier, where it is transformed in a synthetic gas composed of molecular nitrogen (N_2), steam (H_2O), carbon monoxide (CO), carbon dioxide (C_2), molecular hydrogen (H_2), methane (CH_4) and a small fraction of heavier hydrocarbons. Then the synthetic gas is cooled and filtered to eliminate dust, contaminants (cyanic acid, ammonia and hydrogen chloride) and organic compounds (phenols and fatty acids). After being compressed, it is ready to operate the gas turbine where it will be burnt to heat the air to be conveyed to the thermal cycle. In the last section of the plant a boiler recovers the heat contained in the air coming from the gas turbine and produces steam for another turbine, which will operate the electric current generator.

Cofiring

In order to optimise coal plants, it is possible to use biomass as complementary to coal. This is surely one of the cheapest solutions among the energy options offered by renewable sources. The cofiring is based on the replacement of a portion of coal with biomass to be used in the same boiler located in the already existing plant. This can be done by mixing biomass with coal before the fuel is introduced into the boiler or using separate feeding systems for coal and biomass. According to the type of boiler and the feeding system used, the biomass can replace up to 15% of coal in this cofiring operation.

Pyrolysis

Pyrolysis is the thermo-chemical decomposition of organic materials that is obtained through heat application, at a temperature between 400 and 800°C, in complete absence of any oxidizing agents, or with a very reduced quantity of oxygen (in this case it can be described as a partial gasification). The products of pyrolysis can be gaseous, liquid, solid and their proportions depend on the pyrolysis method (fast, slow or conventional) and reaction parameters. One of the main problems linked to the production of energy through pyrolysis is the quality of the products, which has not reached an adequate level in its applications, neither with gas turbines nor diesel engines. For the future, the cycles with pyrolytic oil seem to be more promising, especially for large installations, while diesel engines, that use pyrolysis products, seem to be more suitable for small installations. Direct combustion generally occurs inside equipment (boilers), where the heat is exchanged between combustion gases and process fluids (water, etc.).

Combustion

The combustion of products and agricultural residues has good results if substances rich in structured glucides (cellulose and lignin) and with a water content of less than 35% are used as fuels. The products that can be used are the following: wood in all its forms, cereal straws, residues of dry legumes, residues of oleaginous plants (castor-oil plant, etc.), residues of textile fibre plants (cotton, hemp, etc), wooden residues deriving from the pruning of fruit and forest plants, residues of the agro-food industry.

"Small-modular" systems. These systems could potentially satisfy the energy need of 2.5 billion people that have no electric energy. This capacity is due to the fact that most of these people live in areas where large quantities of biomass can be used as fuel. A small system with a capacity of 5 megawatts could be an excellent solution in villages. Small systems have a potential market also in industrialized countries, as they could be used as a complementary energy supply. Compared to fossil fuel systems, they are a more acceptable alternative also from the environmental point of view.

Carbonization

Carbonization is a thermo-chemical process that allows to transform structured molecules of wood and cellulose products into coal (wood coal or vegetal coal). Carbonization is obtained through the elimination of water and volatile substances from the vegetal matter, due to the action of heat in charcoal pile (cone-shaped wood piles, covered with earth, with a central outlet channel (chimney), where a slow wood combustion takes place, turning the wood into coal). Carbonization occurs outdoors, or in long and curved-neck containers, with a flask shape, that offer a higher coal yield.

Anaerobic digestion

It is a biochemical conversion process that occurs in the absence of oxygen and consists of the demolition, by micro-organisms, of complex organic substances (lipids, proteins, glucides) contained in vegetal and animal by-products, which produces a gas (biogas) made of methane (50-70%) and the rest is mainly CO_2 and has an average calorific value of 23,000 kilojoules per cubic metre. The resulting biogas is collected, dried, compressed and stored, and can be used as a fuel to feed gas boilers and produce heat (also coupled with turbines for the production of electric energy), or to feed combined-cycle plants, or internal combustion motors (boat engines with a low number of turns are suitable for this). At the end of the effluent fermentation process the main nutritional elements that were already present in the raw material are kept intact (nitrogen, phosphorus, potassium), by favouring the mineralization of organic nitrogen. The effluent results to be an excellent fertilizer. Anaerobic digestion plants can be fed through residues with a high humidity content, like animal faeces, civil waste (wastewater), food waste and the organic fraction of urban solid waste. However, also in those dumps that are suitably equipped for the collection of biogases, only 40% of the gas produced can be collected, while the remaining part is dispersed into the atmosphere. As the methane, that largely composes biogas, is a greenhouse gas with an effect that is twenty times as high as CO_2, emissions of biogas into the atmosphere are not desirable. When the decomposition of organic waste is obtained through anaerobic digestion of (closed) adequate plant digestors, almost all the gas is collected and used as a fuel. The recovery of the biogas from dumps is a system that has been experimentally adopted in various countries (England has developed an efficient system of biogas recovery from dumps, both for thermal and electric aims). In Sweden, there are biogas refuelling stations that supply methane vehicles.

Aerobic digestion

It is the metabolization of organic substances through micro-organisms, whose development depends on the presence of oxygen. These bacteria convert complex substances into simple ones, releasing CO_2 and H_2O and highly warming up the substrate, according to their metabolic activity. The resulting heat can then be transferred outside, through fluid heat exchangers. In Europe the aerobic digestion system is used to treat waste waters. More recently, this technology has spread to Canada and the United States.

Biomass plants

Use of biomasses as fuel is advantageous for a number of reasons. First of all, it does not increase the global amount of carbon dioxide in the atmosphere. In fact, the biomasses combustion process frees the same amount of CO_2 as the amount absorbed by the plants during their entire life. Furthermore, use of biomasses such as forest residues, agricultural residues and wood-work residues, contributes to keeping the woods and land clean and creates new work opportunities. It therefore has a favourable effect on employment which, particularly in the rural areas, can lead to a minor dependence on energy from countries producing fossil fuels. Other advantages are its abundance, and the easy way to extract energy, the low sulphur content and as a consequence they do not contribute to the formation of acid rain, and the fact that at the end of the cycle they produce a potential fertilizer. The different technologies to obtain energy from biomasses are very interesting also due to the fact that to obtain energy from this source means exploiting raw materials that currently are a cause of pollution (waste dumps, septic tanks, forests and land that are not cultivated and/or abandoned, etc.). Furthermore, it encourages an effort to plant a rotation of new forests in the areas that have been left bare, with a consequent advantage for the hydrogeological resistance to landslides. And, by controlling the forests and carrying out any activities related to the forests, makes it less easy for the pyromaniacs to carry out their activities. However, it must be pointed out that also exploitation of biomasses has an impact on the environment. In some cases, use of wood as fuel, if it is not carried out according to the principle of sustainability (i.e. taking care to replace the heritage of trees that have been cut) can lead to a progressive deforestation. At present in some areas that do not have many alternative energy resources, this impact is reported. At present, most of the energy coming from biomasses derives from firewood. There are some countries in the Third World, especially in Africa where over 70% of the energy requirement is obtained from fire-wood combustion, a resource that, due to excessive exploitation in some areas can no longer be considered renewable. Furthermore, intensive cultivation of some plants, in view of a future production of energy (the so-called energy crops) require vast areas of the territory in order to obtain significant quantities of fuel (land that is subtracted from agricultural activities for the production of food), and can involve use of fertilizers and other substances that pollute the land and the water.

Biomass district-heating

A district heating system consists of a transport network and a heat production plant, which serves more than one building at the same time. The district heating plant can use co-generation technologies and/or renewable sources.

The installations. The heat that is distributed by urban district heating systems derives from simple production installations (only heat) and combined production installations (heat + electric energy).

The first type of installations includes boilers for the production of heat as vapour, hot water, superheated water, oil. Combined production installations, instead, are co-generation plants that in today practice can be fed by a vapour cycle with internal combustion motors, gas turbines, with a combined cycle.

The distribution network is the most expensive part of the district heating plant: its cost should amount to 50-80% of the total investment. The distribution system can use different types of fluids: the trend in Italy is to use hot water (80-90°C), or slightly superheated (110-120°C). ***Heat distribution.*** The distribution system can be direct or indirect. In the first case, a single hydraulic circuit connects the production plant with the user's heating body (radiator or plate). In the second case, there are two separate circuits that are in contact through a heat exchanger. The direct system requires a lower investment and causes fewer heat losses.

An excellent solution

The excellent solution to exploit biomass, as well as the use of individual heating in pellet boilers (wooden balls) or nipper boilers, is the district heating with small-sized biomasses (10 megawatts), that supplies heat to households and/or business activities, and is located close to the biomass production site (wood, farm land, sawmill, etc). If the biomass is produced locally, the dimension of the plant has to be carefully decided, in order to allow sources to regenerate. Sizes bigger than 10-15 megawatts force to excessively increase the supply, therefore increasing economic and environmental costs of transports on the one hand and going at the disadvantage of the wood sector (production, processing and the sale of products) on the other hand. In Austria small rural district heating plants with biomass are more than 300, with a power included between hundreds of kilowatts and 8 megawatts. In Italy, instead, plants are only a few tens, although the sector seems to be very vital. One of the main reasons for the success of these plants is Austria is linked to the fact that the agricultural economy concentrates on forest activities. There is also a reduction in the wood demand; this led to a price drop and provoked problems to the agricultural sector, forcing to find a solution that could allow prices to go up to an acceptable level for local producers. The majority of district heating plants was created in rural and economically depressed areas, but also many tourist sites have devoted attention to this technology, based on very low emissions. They saw this renewable source as an element for tourist promotion. Also in Italy these plants could be the answer to the depression of some areas, with the creation of new jobs for the maintenance of forests (economically and environmentally convenient activity), and the prevention of erosion, landslides, floods and fires. Biomass district heating is to be considered as a complementary technology, not be seen as an antagonist of domestic biomass boilers. District heating installations, with grill boilers, can burn all types of wood waste, although it is very wet and with a low calorific value.

Household wood boilers, instead, cannot use these types of waste. They burn dry and quality wood, of adequate size, or it is necessary to opt for pellet boilers in order to automatize the installation, avoiding to have to supply it continuously (even several times a day in winter). This wood, in fact, occupies less room with the same quantity of dry mass being burnt, guarantees a more regular combustion and a simpler transport/storage. This variability in the supply system of biomass installations allows to exploit all the products deriving from wood maintenance: the waste (branches, barks, roots, etc. also very wet) is used for district heating if there is an adequate number of users, while dry trunks and pelletized waste for isolated households. The residues (of wood cleaning, agricultural farming, sawmills, etc), without a biomass-supplied installation, would be disposed of in a different way: if they were left in the air they would produce the same quantity of CO_2 as was stocked during their growth. If fermentation occurred in the absence of oxygen, methane would be produced, whose contribution as a greenhouse gas is 21 times (in terms of weight) as high as the weight of CO_2. If these residues are disposed of in factories (paper mills, etc), they often impose quite high transport costs (environmental and economic ones). In order to plan the construction of a biomass district heating installation, it is necessary to satisfy the following pre-requisites:

- the distance from the supply site cannot be too big, as the transport can significantly affect the cost of the raw material (and the quantity of CO_2 released by the installation);
- the closeness to the supply source can allow to have a smaller storage volume inside the district-heating plant (allowing to build it also in narrow areas), having the chance to do the storage at the supplier’s place;
- it is necessary to have an adequate area, close to the transport network and conveniently close to the households, where the installation and the storage warehouses will be built, without having too many problems due to the traffic.

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