Energy from waste

Refuse derived fuel

In the context of the waste-to-energy strategy, we find the so-called refuse derived fuels (RDF) obtained from non-dangerous waste, and used to recover energy in incineration plants (also known as Waste to Energy systems). The range of waste materials that are used is very large and includes the residues which have been excluded from the recycling processes, waste from the industries and the distribution networks, muds from water purification systems, dangerous industrial waste, discarded biomass materials, etc. ... These must be treated suitably in order to comply with the criteria, regulations and industrial specifications in order to reach a suitable heat producing potential. One of the least costly methods, which is most widespread, for the production of RDF, is mechanical biological pre-treatment, MBT. In a MBT plant, metals (which are recycled) and inert materials (e.g. glass), and organic fractions (that are sent to the composting plants, with or without an anaerobic digesting phase) are separated from the MSW, and fractions with a higher heat producing power for the production of RDF, are chosen. Other solutions, besides MBT, are bio-stabilization and bio-drying of materials from which metals and inert materials have been removed beforehand, in which the organic fraction is stabilized and loses a part of the humidity, thus obtaining a final fraction with a higher heat producing power, that is suited for combustion, and consisting of paper and cardboard, wood, plastic and textiles that can be burnt directly. The total quantity of RDF produced from MSW in the European Union is estimated around 3 million tons. The Italian production amounts to 200,000 tons with a yield of 300 kg per ton of MSW. The characteristics that are necessary for the product that is obtained with the treatments to be used as RDF are many, and include a heat producing power of at least 15 MJ and 25% humidity.
Which are the current uses of RDF? There are numerous possibilities, which include: Waste to Energy systems, cement plants, thermal energy plants for district heating, steel plants, coal thermo-electric power plants etc. and, depending on the plant, they are uses as the only fuel or as an auxiliary fuel.

Biogas

Apple peels, fish bones, leftover pasta and a handful of corn, no this is not some kind of strange secret recipe, but some of the elements that are necessary for the production of a very particular combustible, biogas. Biogas is a gas, but unlike methane that is extracted from the ground, it is produced from the decomposition of organic material (the organic waste of our waste), civil and zootechnical sewage, agricultural biomasses, etc. in anaerobic conditions, i.e. in absence of molecular oxygen (O_2) or bound to other elements (as in the case of nitrates NO_3). Remember the production of compost? The concept is similar, as there is a decomposition of organic material, however the products and methods for its realization differ. The principal products of the reaction are methane and carbon dioxide and the presence of the former makes biogas suited for utilization as a fuel. However, unlike traditional methane gas, biogas is a renewable energy resource, it can potentially be produced starting from the raw materials that are available locally and waste, if the plants for the production are designed and managed correctly, with a recovery of the material which would otherwise only be waste material to be disposed of. The treatment that is carried out is anaerobic, to stabilize the organic material, to produce biogas and recover waste material in special closed reactors called digesters. In this treatment a natural phenomenon is accelerated by adding heat and continuously mixing the materials, besides controlling important parameters of the process such as pH, temperature, solid content, volatile fatty acids and alkaline content. There is a wide interval of biological activity, which ranges from -5° to +70°C, coming from three different classes of anaerobic microorganisms, each activity in a certain temperature range. Initially the anaerobic digestion process only had the scope of stabilizing the organic material, however at present industrial systems for the production of biogas are created, starting, as mentioned above, from water from the food and agricultural industries, muds from sewage water treatment plants, animal faeces, biomasses from agriculture, industrial organic residues and the organic fraction of urban waste.
But, how much and what can we obtain from anaerobic digestion? Average process values indicate a production of biogas of about 100-150 m^3/t, where CH_4 is equal to 60-65% of the volume, CO_2 is equal to 35-40%, and the heating

power is equal to 23-25 MJ/m^3. The production of biogas can also take place in the waste dumps in a non-controlled manner, therefore it is very important to foresee its capture, for its recovery and also to avoid dispersion in the atmosphere or accidents. The production of biogas has several benefits: 1) biogas is a renewable source of energy produced from waste, and therefore it offers a possible solution from the point of view of energy and of the environment; 2) the production and release of methane in the atmosphere is avoided; 3) the production cycle of biogas is defined carbon neutral, because the carbon dioxide contained in it is the same carbon dioxide that was previously fixed by the plants, and it is not newly created as in the case of petroleum or coal combustion. On the other hand it is necessary to pay attention to some technical aspects, so as not to jeopardize the sustainability of the plant . In fact it is very important that it is built in areas that are suited, possibly near the animal farms, to avoid transporting large quantities of organic material, and to avoid, as far as possible, using dedicated cultures as raw material so as not to subtract an excessive amount of areas from agricultural production.

Waste to Energy systems (WTE)

What to do with all the waste when none of the materials can be recovered? According to the hierarchic waste pyramid, the preferable option are the Waste to Energy systems, in other words incineration with energy and/or heat recovery, before disposal in the dump (where neither energy nor material can be recovered). In the Waste to Energy system, or in the Incinerator, waste is burnt, and the heat producing content of the waste is exploited (remember, plastic is produced from petroleum and therefore has a high heat producing power), heat is generated, water is heated to produce steam in order to obtain electric energy. This energy can be used to produce heat, to produce electricity or for the combined production of heat and electricity (cogeneration). Furthermore, with the Waste to Energy systems it is possible to decrease the mass of waste by 80-65%, and the waste volume by 96%. Up to about 20 years ago, waste was burnt only to decrease its volume and to make it inert without any energy recovery. However today the situation has changed and engineers, researchers and technicians study how to improve these plants from a technological point of view, making them increasingly safe and efficient. In many countries Waste to Energy systems are already a consolidated alternative (e.g. Japan, Sweden, Denmark), while in Italy, only 19% of the waste is incinerated. Which part of MSW is burnt? The “combustible” fraction consists mainly of paper, plastic, organic waste (grass, wood, food leftovers) and from an energy point of view waste can, in some ways, be compared to fossil fuels, as these are organic materials which contain elements that can be oxidized (carbon and hydrogen). The Waste to Energy system is complex, and involves a number of chemical reactions, whose results depend on the operative conditions that are utilized and the technologies and processes that have been developed specifically for MSW, with the following possible operative solutions:

- direct combustion, where waste is burnt and the thermal energy of the heat is transferred to a thermal vector (steam);
- conversion into an intermediate liquid or gas fuel, by means of pyrolysis or gasification.

Combustion takes place in special furnaces, in 4 different stages: heating and drying, pyrolysis, combustion and/or partial oxidation, combustion and/or gasification of the carbon material. Besides the heat generated by the combustion, also ashes and gas emissions are produced; both these require special treatments to reduce their polluting load, so that they can be released in the environment without any risks for our health. The heat developed by combustion of waste is recovered and used to produce steam. In turn the steam that is generated activates a turbine that is coupled with an alternator and a gearmotor, and converts thermal energy into electric energy; alternatively the steam is used as a thermal vector. How much energy do we obtain by burning waste? The yields of the Waste to Energy systems are however lower than the traditional electricity power plants, due to the low heating power of the waste: the efficiency is therefore variable and ranges from 17% to 25% (30% may also be reached in the more forced cycles), and increases to over 50% in case of heat recovery, producing indicatively 0.67 MWh electricity and 2 MWh heat for district heating systems per ton of treated waste. This has not prevented some cities from using this solution to optimize their energy demand and for their waste disposal, as for example in cities like Oslo, Paris and Vienna.

Gasification and pyrolysis

Combustion by means of incineration can be one of the solutions for recovering the energy content of waste, however it involves numerous difficulties, among which the emission of gas effluents that require a costly purification treatment and that have induced researchers and engineers to search for more solutions for the plants. Among these are gasification and pyrolysis, which are being experimented as a potential alternative to the Waste to Energy systems. Even if in the waste sector, innovative technologies are being considered, gasification and pyrolysis have a more ancient history that dates back to the 18th century. The first applicative examples made use of coal, while waste started being used from the 90s. How do these Waste to Energy systems differ one from the other? During combustion, the combustible elements that are present in the waste are oxidized in the presence of excess oxygen, which produces a release of heat and waste products, such as combustion smokes and inert solid residue. Diversely, during gasification the conversion of a solid or liquid material into a combustible gas (syngas) takes place through partial oxidation in which air is used in minor amounts than what would be necessary in order to complete the reaction, and a gas, enriched with carbon oxide (CO) and hydrogen, is obtained. Finally, unlike in the case of combustion, pyrolysis is carried out in absence of oxygen and consequently it is possible to obtain three products in different phases, all are fuels: syngas, tar (a condensable substance that is present in syngas, in the form of a liquid product) and char (carbon residue).

But what are its uses? Syngas can be used as a fuel or raw material in the chemical industries, tar can be used in various ways, among which for co-combustion with coal for the production of electric energy, as fertilizers, as fuel for thermo-electric power plants, etc., finally, char can be treated with hydrochloric acid for the production of coal, or with carbon dioxide for the production of activated carbon, a material that is used for water purification. From 1 kg of MSW, by means of a pyrolysis process, 0.15 to 0.3 kg of syngas, 0.5 to 0.6 kg of tar and 0.2 to 0.3 kg of char, are obtained. Gasification involves a greater production of gas than the other two components.