WASTE MANAGEMENT

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Introduction

The term management includes all the activities regarding collection, transport, recovery and disposal of waste, while the term integrated waste management indicates all the activities aimed at optimizing the said management. An integrated management system is the practical transposition of the principles set out in the Italian Laws, and the European Directives.

Waste disposal

There are many different aspects that must be considered in the correct planning of an integrated management system and all these contribute to the choice of the most suited solution for disposal of the waste produced in the situation which is being examined. First of all it is important to evaluate the qualitative and quantitative characteristics of waste, the aims of separate waste collection must be established, and also the transportation utilized, waste treatment and disposal plants that can receive the waste must be identified. Having evaluated these variables, the next step is the examination of the available operative instruments, with different possible options: separate waste collection, plants for pre-treatment of waste before disposal, plants for energy recovery, (such as incinerators, gasifiers, etc.) material recovery plants, and controlled dumps. When all the data has been collected, the appointed technicians and engineers and researchers will choose the best solution using a series of instruments such as: mass and energy flow, environmental impact assessment (EIA), economic assessments, life cycle analysis (LCA) and risk analysis.

Recycling

By the word recycling, we mean the set of operations, strategies and methods that are used in order to recover the materials and to reduce the quantity of waste sent to the dumps and incinerators. As pointed out before, man has always been used to recover his goods or to recycle his waste up to the industrial revolution. Starting from that time, the massive production of consumer goods and the great availability of resources did not make modern man feel the need to give his waste a second life. Everything started changing from the Seventies when the costs of energy and the awareness of living on a finite planet with limited resources led to the application of measures to reduce human pressure. As noted before the European Directives and the Italian Legislation indicate prevention and reduction of waste upstream, as the first feasible choices in the area of waste management (waste hierarchy). In case this is not possible, measures for the preparation and reutilization of waste follow, and subsequent to these, measures to recycle waste.
Only some waste, of specific categories of materials, can be recycled. These categories of materials usually follow a separate course and are collected through a specific system of separate waste collection that we have started to experiment daily in our homes. The separate collection systems that are proving to be more efficient and economically sustainable are those related to raw materials that the packaging is made of (paper, glass, plastic, aluminium and wood). In order to simplify the

management, collection and disposal procedures, specific consortiums have been created for each of these categories of materials. The efficiency in the recovery is often very high. This success can be explained in two ways: firstly, even after having carried out their function, these materials have a sufficiently high market value which justifies the investment effort; furthermore, as a result of the commitment of the consortiums, of the producers and distributors and also us consumers, very high levels of efficiency have been reached, over the years.

Incineration

Incineration, with energy recovery (Waste to Energy systems) is another solution to dispose of waste and consists in the combustion of waste in order to:

- decrease the volume and weight of the material;
- to completely oxidize the waste into CO_2 and H_2O;
- recover the energy content of the waste;
- sterilize the residues.

The characteristics of waste produced in our homes is such that other fuel is not required for its combustion, the waste that is fed into the incinerators is sufficient, alone, for the combustion. What happens to the waste during the process? The carbon, hydrogen and sulphur content of the waste is oxidized forming CO_2, H_2O and SO_2. The humidity in the waste is transformed into steam, while the presence of halogens (Cl, F, Br) and Nitrogen produce acid substances and Nitrogen oxide (NOx) respectively. Lastly the metals may undergo phenomena of volatilization and inert matter becomes slag. A simplified Waste to Energy plant includes a front pit, i.e. a separate area where the waste arrives that limits the spread of bad odours, an accumulation and mixing pit, where the waste is dumped and the incinerator. Incineration provides a series of advantages among which maximum reduction of the volume of the waste and energy recovery, but also a series of disadvantages that involve numerous problems, such as control of the polluting substances produced during combustion, disposal of the residues and a particularly complex management. Even though in Italy this solution has often been prevented and is scarcely utilized, in Europe it is a widely prevalent type of plant solution, and many cities use the energy produced by their waste, in order to guarantee operation of their systems.

The waste dump or landfill

In the controlled type of dump, waste is deposited in layers on the ground, in a suited and monitored manner, so as to minimize the negative effects on the environment and on human beings. Thus, pollution of surface and underground water is prevented and controlled, as also emissions of unpleasant or toxic substances, and all efforts are made to reduce the aesthetical impact. Even though the disposal of waste in dumps is the least efficient type of waste management, in Italy this is still the solution that is mostly adopted in almost one case out of two.

Dumps can be subdivided into three different areas: an internal mass, which is the largest area, where degradation of putrescible waste takes place in absence of oxygen (anaerobic degradation with the formation of biogas), a superficial layer, that acts as an interface between the solid mass

and the air; the leachate, the liquid produced by rainwater percolating in the waste and the humidity content of the waste. Waste dumps are created by successively filling layers of a suited height (maximum 2.5 m) starting from a bottom layer that has been suitably waterproofed with natural materials (clay or a mixture of sand and bentonite) or artificial materials (geomembrane made of PE and PVC). Once the layer of waste has been laid down, it is compacted with mechanical equipment (bulldozers or compactors) to decrease the volume these occupy, up to a density of about 800 kg of waste per cubic metre. Every day, the waste is covered with inert material such as soil or gravel, and when the dump is fully filled, it is entirely covered with vegetative land, and usually it is converted into a green area. An important element of the dump are the drainage system and the system for the collection of biogas and the leachate, to avoid contamination of the area.
All this occurs in controlled waste dumps, however often the dumps are associated with very negative characteristics, because of the risks involved for the environment and human health, besides their unpleasant aesthetical problem.
This is true with regard to non-controlled and illegal dumps that are very dangerous. Controlled waste dumps, per se, are not negative, but their utilization must be limited as much as possible and only where valid alternatives are not available. As we have pointed out before, in fact, the waste dump is the last solution in the hierarchy of waste management alternatives. There are many reasons for this: first of all, waste sent to the waste dump is no longer useful and from this waste nothing can be recovered neither as a material nor as energy; furthermore, the waste dump needs large amounts of space in order to be constructed, and a large effort with regard to the costs and for management of the same. The space and the resources that are available on the planet are not infinite and, in this view, use of waste dumps implies a large amount of wasted resources.

Separate waste collection

With the Ronchi decree, separate waste collection was started in the Italian homes, and has now become part of our daily activities, and the small yet big contribution that we can give to the environment. Separate waste collection is the process in which domestic separation of waste is carried out with the aim of re-addressing, upstream, the various types of waste that are present in our homes and to optimize management of the same.
MSW materials that are collected separately often consist of the packaging of products we have purchased such as: paper, glass, plastic, aluminium, wood, humid or organic fraction, electronic waste (WEEE- waste electrical and electronic equipment) and bulky waste.

Paper

Paper is the material with the highest recycling rate in our country. Collection is extended to all types of paper, including drawing paper, paper for graphic use, for photocopies and for newspapers, cardboard and paper bags. However soiled paper (like the boxes used for pizza delivery) must not be put in the separate waste collection, as it might pollute and contaminate paper that can be recycled. The consortium of companies that collect and manage this packaging is called Comieco.

Up to the 90s, Italy imported large amounts of raw material from Northern Europe in order to supply the paper industries, while now Italy is an exporter of recycled paper and cardboard. The paper recycling cycle starts with the separation of the different types of paper and cardboard that are brought to the specific plants: packages, discarded cardboard, mixed paper. After being sorted out, the paper is shredded with the help of special machinery, known as a pulper, and it is sifted in water to remove the contaminants, and finally also the glue and ink are eliminated. Subsequently the pulp that is obtained is mixed with raw material. In fact, the process weakens the cellulose fibres that form the paper, making them short, and therefore it is necessary to include an additional amount of virgin raw material, so as to obtain the same characteristics of the standard material. This degradation takes place every time the material is recycled and it has been noted that the maximum number of times that paper can be recycled is 4. Saving, in terms of materials and energy is remarkable. By recycling paper we save 30% energy, 50% water, and 100% material as no trees need to be felled. However, the paper whitening process often requires use of chemical compounds, like bleach, that can be particularly polluting for the environment. Lastly, according to Comieco, 1.31 tons of CO_2 eq are avoided per ton of recycled paper. Therefore, paper recycling has a double advantage for our country. From an economic point of view imports of virgin raw material are decreased, and also the amount of material that is disposed in the dump decreases. From an environmental point of view there is a remarkable saving of energy, water and raw materials.

Glass

Glass is both fragile and eternal, and it is one of the most interesting materials from the point of view of recycling. Because of its physical and mechanical characteristics, it is a particularly interesting material that does not become degraded qualitatively during the recycling process and can be reutilized practically an infinite number of times. A bottle that is melted again in the furnace of a glass industry, will generate another bottle with the same qualities as the previous one, and this total recyclability enables a remarkable energy saving in the melting phase. The glass that is collected initially is subjected to a first selection, in order to remove any polluting materials, it is then crushed and any metal parts are removed. A final manual separation takes place in order to remove any ceramic and metal residues that may still be present. The material that is obtained is called glass cullet which is ready to be melted in the furnace. At this stage the glass production phases begin, which include mixing sand (silica) with limestone, soda and additives, plus a variable percentage of crushed glass (up to 90%). The materials are baked in special furnaces up to 1500°C, in order to reach the melting point. The vitreous mass that is obtained is sent to specific machinery where it is blown in moulds and transformed into new containers. Use of glass scrap requires a lower temperature for the material to melt than the raw materials and produces less atmospheric emissions. Furthermore, out of 1 kg of glass scrap 1 kg of new product is obtained. Energy and material savings are very significant, equal to 25-30% and 100% respectively, and there is a 40% decrease in CO_2 eq emissions.

Plastic

If we look around, we will see that many of the objects that we use daily all around us are made of an extremely versatile, light and economical material, plastic. The toothbrush, the cover of the mobile phone, pens and felt pens, the computer, the television, all these objects and many others contain at least some plastic. However, there isn't only one type of plastic. Items made of this material are of many different types, and it is sufficient to compare the plastic supermarket bag and the bottle that contains a detergent to immediately see a number of differences. The term plastic in fact is usually used to classify different families of polymers, i.e. long chains of molecules with a high molecular weight consisting of a large number of molecular groups, derived from petroleum refining and containing carbon, hydrogen, oxygen and chlorine. Each type of plastic corresponds to a different material, with specific. physical, chemical and mechanical characteristics. This heterogeneousness implies different recycling processes, depending on the polymer or the family of polymers that are treated, so that in this case it is not possible to speak of plastic recycling in general, because actually there are many plastics. The most common and most widespread in daily consumption may be subdivided into two large groups: thermoplastic material, that softens in the presence of heat and becomes hard when cooled, and thermohardening material that solidifies irreversibly when heated. Thermoplastic resins are the easiest to recycle and among these categories the most common in our daily use are:

- PE, polyethylene, generally bags, bottles and film are made of polyethylene – depending on the type of processing it is subjected to;
- PP, polypropylene, used for a large number of different items from food trays to garden furniture;
- PVC, polyvinylchloride, for trays, film, pipes;
- PET, polyethylene terephthalate used for bottles for soft drinks and mineral water, synthetic fibres;
- PS, polystyrene, better known as thermocole used mainly for corks, plates, cutlery and trays for foodstuffs.

The recycling procedure can be mechanical (more common), or chemical. Firstly, in case of the mechanical recycling procedure, the material collected through separate waste collection must be selected so that any foreign bodies are identified and eliminated, and the different types of packaging are sorted according to the type of polymer and colour wherever possible. In order to guarantee high yields, selection of the different plastic materials is fundamental. The sorted material is then sent to the recycling line where it is crushed, washed, ground, dried and finally granulated. In the final phase granules or flakes, that can be used in transformation plants, are obtained. Chemical recycling instead is applied on an industrial scale, and it is aimed at breaking the polymer macromolecule into its simpler individual units (monomers), to be used as new raw material. The granules and flakes can be used for different purposes depending on the initial polymer: for example, PET bottles are used to produce fibres and textiles (such as pile blankets), PE is used for bottles and containers, PVC is used for pipes and sewage plumbing, and electrical materials. In Italy, separate waste collection is only carried out in the case of plastic packaging materials, for which the percentage of recovered product is however high. Furthermore, unlike paper and glass, for plastic, also energy recovery may be foreseen (remember, plastic is obtained from petroleum) as its lower heating power, i.e. the amount of heat that is freed during combustion, is sufficient to justify this option (30-35 MJ/kg). How much do we save by correctly recycling plastic? Energy saving is high, from 40% to 90%, with an average of 50%, while the saving of material is 100%! If we avoid sending plastic to the dumps and we recycle it correctly, we avoid emissions of 1.39 kg CO_2 eq per kilo of plastic, and therefore contribute to contrasting the increase in carbon dioxide emissions in the atmosphere.

Wood

Wood is a rather uncommon material in our daily separate waste collection, however it is not less important than the others. Wood, like plastic, does not always have the same characteristics. In fact, there are many different kinds of wood, that are used in different ways depending on their nature. In any case recycling wood is very important for two reasons: firstly, natural resources are preserved, since by recovering the material less trees are felled, and secondly, by avoiding sending wood to the dump there is a saving in emissions in the atmosphere of methane and carbon dioxide, which are gases that alter the climate. With regard to household separate waste collection, wooden items are mainly furniture, interior decorations, doors, fixtures and various bulk items, while wooden packaging is present in negligible quantities in the form of crates for fruits and vegetables, prestigious boxes for wines, liquors and distilled alcohol, small boxes for cheese corks, and occasionally pallets.
For this reason, wooden materials follow a separate circuit and are collected locally after contacting the appointed consortium, Rilegno, or they can be personally taken to suitably equipped stations or ecologic areas that are made available for the citizens. All the wood can be recycled and the resulting material is of a good quality. Wood waste that is collected, is prevalently subjected to mechanical recycling. The material from the platforms is selected and cleaned so as to eliminate any foreign bodies (metal, paper, various plastics, inert materials), after which it is chopped into small chips that are ready for use. These chips, after a drying process that is necessary in order to limit the level of humidity, are pressed with glues with a very low formaldehyde content, in order to produce chip-boards, which have the same characteristics as new chip-boards, used in the production furniture, interior decoration accessories and coverings for indoor and outdoor structures in homes and offices. 95% of wood waste is processed in this way. The remaining amount is used for the production of cellulose paste for the paper mills or is subjected to treatment that makes it suited for use as a raw material for the realization of wood and cement blocks that are used in green building projects. A small part can be used in composting plants, for the production of compost or loam for sale on a large scale. Lastly, wood waste can be transformed by means of various processes into solid fuel for incineration plants or for biomass combustion plants for the production of heat and energy. Another regeneration method is foreseen for pallets, which can be separated and re-introduced in the consumer circuits.

Aluminium

Aluminium is light, versatile, durable and quite malleable. This metal has exceptional characteristics

that make it particularly suited not only for the production of cans but also for car parts and for use in buildings. Recycling aluminium is very important because its production is a particularly costly one from the point of view of material and energy, in fact aluminium is obtained from bauxite which is a sedimentary rock, and 4t of bauxite and 14 MWh of electricity are required in order to obtain only one ton of aluminium.
What happens to our cans after they have been thrown in the separate waste collection bag together with plastic or glass? Collection of aluminium is generally carried out as a multi-material collection, i.e. together with other types of materials such as plastic, because of the costs involved. The first step towards recovery is the separation of the cans from other packaging materials, after which the aluminium is crushed and separated from any iron residues. After which the cans are treated at 500°C in order to remove any paint or adhesive substances. Finally, they are melted at 800°C and new materials are produced. Among the advantages of recycling aluminium, there is the absence of a decline in the quality of the material during the process. As a consequence of this characteristic, this material can be recycled an infinite number of times, with remarkable energy savings (electric energy saving equal to approximately 95%), as the production process of bauxite and the material is particularly energy demanding. Also, energy recovery is possible. Aluminium powder and sheets, in fact, can be assimilated with fuels and, when heated up to 850°C, 1 kg of aluminium releases 31 MJ of energy, the same energy released by 1 kg of coal. Saving of energy and resources is very high: 95% energy is saved and 100% of material.

Waste electrical and electronic equipment (WEEE)

In Italy, the acronym WEEE stands for waste electrical and electronic equipment. In this category, many types of waste that differ in composition, method of utilization and characteristics, but which are all afferent to electronic devices, are grouped - i.e. all the devices that use electric energy for their operation. WEEE can be of two types: domestic and professional, which are then subdivided into 10 categories:

- Large household electrical appliances
- Small household electrical appliances
- IT and telecommunications equipment
- Consumer equipment (consumer electronics)
- Lighting equipment
- Electrical and electronic tools
- Toys, leisure and sports equipment
- Medical devices
- Monitoring and control instruments
- Automatic dispensers

In this category of waste, a number of different substances and materials can be found, such as plastic metals, chemical substances, etc. and for this reason their correct disposal and recycling is rather expensive. Up to not long ago, this waste was erroneously disposed of in the dump, which involved severe risks for health and the environment. In order to avoid this damage, the European

Union and its Member States promulgated a series of measures in order to manage this type of waste correctly.
How are these special materials recycled? There are 4 phases in order to recycle WEEE: separate waste collection, making the materials safe, treatment and recovery. Separate waste collection of WEEE is carried out by the end user, who, in this case is not always the consumer, but can also be a retailer or the Company that is appointed to take care of the same. For the citizens, collection points are usually available, or a service for collecting the equipment directly at home, which is an alternative to the door to door collection. Professional WEEE is collected directly at the premises of the company, organism or plant. WEEE that is deposited is taken care of (in Italy) by ReMedia a consortium that is in charge of treating the materials and making them safe. This is because WEEE often contains harmful substances that must be separated before they are treated and must be removed so that it is easier to recycle the materials. Waste is subjected to inverse production lines that break up the materials and transform them in order to recover the raw materials that can be utilized again in new production cycles.

Organic waste

What happens to a banana skin when we throw it away? If we want to try an experiment, and we leave it in a garden, we will notice that in a short period of time the skin will transform and disappear completely or almost completely, leaving a new organic substance in its place which is then absorbed by the ground. This happens because the banana is an organic waste and it is biodegradable like kitchen leftovers and garden cuttings, and therefore decomposes easily and is transformed by saprophytic bacteria. So can we also think of recovering organic waste? And if so, how? Organic waste is transformed by means of a biological treatment, composting, in order to recover the organic material that is present in this waste and to obtain a new material called compost. Compost is not a fertilizer, but is defined an organic amendment, because it adds an organic substance and nutrients to the soil (nitrogen, phosphorus and potassium), consequently leading to a decrease in the use of chemical fertilizers. The process consists of the decomposition of the organic substance by microorganisms, in aerobic conditions, i.e. in the presence of oxygen. The principal products obtained from the compost reaction are CO_2, water and heat. This is a natural phenomenon that is forced by insufflation of air and by periodically turning over the material, in order to accelerate the reaction. Compost production times vary depending on the material and the period of the year, indicatively from 2 to 6 months. Microorganisms are the main promoters of the process, and they are many and of different strains – bacteria, fungi, algae, protozoa, etc.) and usually they are naturally present in sufficient amounts in leftovers; however, so that they can carry out their function correctly, they must be in optimum conditions. Therefore, in the production of compost, it is important to pay attention to some parameters: oxygen, sufficient porosity of the material in order to guarantee circulation, humidity and the Carbon/Nitrogen ratio. The starter materials, which must be used in compliance with the law, are: the organic fraction of MSW collected separately; plant waste from agricultural crops, sawdust, wood chips, wood fragments, zootechnical sewage, paper

and cardboard (in small quantities), mud from civil sewage purifiers and discarded wood that has not been used and has not been treated.
Dangerous waste and materials which have undergone chemical treatments are strictly prohibited and, lastly, also inert substances that would hinder the degradation process. In fact, it is very important that the compost does not contain polluting substances, heavy metals and pathogenic agents. During the composting process, the materials are suitably mixed in order to obtain an optimum C/N ratio. For example, humid materials have a low C/N ratio while dry materials that act as structuring layers have a high ratio. Two main stages are identified in the composting process: the first phase, ACT (active composting time) is an accelerated bio-oxidation phase in which the waste is highly putrescible, and the metabolic process is very rapid and there is a large consumption of oxygen, a maturing phase in which the metabolic process is slowed and the consumption of oxygen decreases, besides any refining process pre-treatment or post-treatment. Depending on the quality of the material, it is used in different ways: to fertilize the land (mixed with manure), mulching, as soil for covering waste dumps, etc. Composting can be carried out on a domestic scale with small volumes of individual humid waste collection plus other selected materials, or on an industrial scale where large volumes are used and all the physical and chemical parameters are suitably monitored in order to obtain a good quality compost that can be sold in the market. Domestic composting can easily be carried out in composting bins of various sizes (usually 30 or 60 l) which are sold in the market.

Energy from waste

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.

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