Waste

Introduction

In our daily activities, we produce a lot of waste. When we unwrap a packaged snack, or leave some broccoli in our plate, or if we decide it is time for a new videogame, we are saying that we no longer want to use those things and therefore we want to get rid of them. It is a very simple gesture, once decided, we throw everything in the trash and when it is full, we throw the bag full of rubbish in the large bin outdoors. From this moment onwards, there are special services in charge of managing our waste and the problem is solved for us. Actually behind waste there is a lot to know and a lot that we can do. First of all, what is waste?

What is waste?

What is waste, and how is it created

We can say that waste is a substance or an object that the person who has produced it, wants to get rid of. Often we only see the waste in our trash can, and it does not make us worry, but actually waste is a serious problem for the Planet. Why?

In nature, the concept of waste does not exist. In fact, in biological cycles whatever is discarded by one organism becomes a resource for other living beings so that nothing is wasted and everything is transformed. Dead organisms, animal faeces, or plant remains are defined organic waste and are used as food for particular organisms known as decomposers, that transform the waste products of other living beings into precious resources and are therefore very important.

Up to the last century, man behaved very much like nature. Specially in the farming society, due to the lack of resources everything was utilized and nothing was thrown as long as it was useful. Almost all that was thrown was organic and was disposed of by the decomposers in nature.

The advent of the industrial revolution and the increase in goods brought into society, also determined an increase in the consumption, and therefore an increase in the amount of waste. In fact, in the current social and productive models, after withdrawing material and energy from the environment in order to produce consumer goods, the production of waste follows. Waste is not only organic as in the pre-industrial society, but is also inorganic (as in the case of plastic) and often waste remains in the environment for a long period of time as it is not a source of food for any organism. This implies two things: first of all waste is generated by us during our daily activities, and by the industries that produce the products that we make use of to live, but also there are no cleaners that re-use a large part of our waste, and therefore it accumulates in large quantities. Human beings are trying to find some solutions. Which?

Waste in pre-industrial society ...

Even though in the past human beings produced small amounts of waste, the problem of where to deposit the same existed even then. Whatever could not be recycled or reutilized was often thrown on the road, with severe consequences for health. Alternatively waste was burnt or buried underground outside the inhabited centres, thus giving rise to the first waste dumps. Waste in ancient times was very different from ours. Waste was organic and consisted mainly of products that were discarded by the workshops and kitchens, human and animal waste, carcasses and their remains. The first humans who thought of waste disposal by burying waste underground were our ancestors – near their prehistoric settlements, in fact, archaeologists have found the remains of their meals (the bones of the prey they hunted) and small tools and earthenware. Instead, it seems that the Greeks were the first to feel the need for a public town-cleaning service, and a group of sweepers were appointed (probably slaves) to clean the city of Athens. During the Roman

Empire, the Romans established the first public service for waste collection and disposal, and they exported this model all over the Roman Empire. In the Middle Ages the situation worsened remarkably and the citizens considered the road a privileged place where to get rid of their waste. In this period the forerunners of city waste dumps were born, cavities that were known as *butti.* The few inorganic waste products were disposed of differently. Before becoming waste, the objects changed owners various times, passing through the entire social chain. In ancient societies, and up to the dawn of the industrial society, whatever was thrown away, because it was considered useless by the rich, became precious for the poor.

… and in the consumer products' society

A big change took place in the second half of the XIX century. With the Industrial Revolution an intensive exploitation of the resources began. Industries started the mass production of items, that were more economical than those made by craftsmen and therefore more accessible to all. Soon humans passed from a frugal and semi-agricultural society, to an industrial consumer society, that adopted disposable objects as their style of life. Since some decades, objects are no longer repaired, nor are they reutilized as they can easily be replaced by other new ones. The result has been an excessive production of waste in relation to the planet's capacity to dispose of it, thus becoming the negative symbol of riches and wellbeing. With the industrial era also the kind of waste changed. Besides the increase of glass, metal and organic wastes, new materials, as for example plastic, have appeared, and as these are not biodegradable, they remain in the environment for a very long time.

Waste in numbers

Which waste

The waste we produce every day is defined Municipal Solid Waste (MSW) and includes whatever is discarded during our daily activities. All other waste is defined special waste, which includes waste produced by industrial activities, handcrafts, hospitals, etc.

In order to simplify waste management, MSW is subdivided according to its composition, also known as the product fraction. There are six main categories: 1) recyclable materials (paper, plastic, glass, etc.); 2) compostable materials (kitchen leftovers, garden trimmings, etc.); 3) bulky materials (sofas, furniture, etc.); 4) durable goods, waste electrical and electronic equipment (computers, TV sets, refrigerators, etc.); 5) dangerous urban waste (batteries, drugs, car batteries, etc.); 6) residue (whatever is not classified in the previous categories).

MSW can be considered a kind of documentation regarding the use and life-styles of those who produce them. In fact the types of waste differ not only from one state to another but also within the same state (for example, waste produced by a town and by the countryside, or by different areas of the same town). If we analyse the average hypothetical rubbish bag of the Italians, we will discover that most of the waste produced, up to 40% of the total, consists of compostable materials. The other main component of our waste consists of recyclable materials (about 48%) subdivided according to the raw material they are made of: paper and cardboard paper (20-30%), glass (7-10%), plastic (10-14%), metals (4-6%), wood and textiles (5-7%). The remaining part consists of durable and dangerous waste.

How much waste

In general, it can be stated that, as in the past, the production of urban waste is proportional to riches, or better to the pro capita Gross National Product (GNP). In most cases, in fact, the inhabitants of the rich and industrialized countries produce more waste than those in the poor and developing countries. In the European Union, in 2014, the States with the largest production of urban waste were Germany (50 million tons), France (33,7 million tons), Italy (29,6 million tons) and the United Kingdom (31,1 million tons). Most of the pro capita production instead, was from Denmark (758 kg/inhabitant

per year), Cyprus (617 kg/inhabitant per year) and Luxemburg (616 kg/inhabitant per year). In 2015 in Italy, about 29.5 million tons were produced, with a pro capita production of about 486,7 kg: this means that each one of us produces an average of 1.3 kg of waste per day. These quantities can become equally precious energy resources and raw materials, but an integrated recovery and treatment system must be created, as foreseen by the Ronchi Decree. Otherwise large quantities can mean only big problems with regard to management and impact on the environment.
(*Source: EUROSTAT; ISPRA, Rapporto Rifiuti Urbani, 2016*)

Laws regarding waste

Waste management and legislation

Up to the Seventies, Municipal Solid Waste (MSW) was collected without any separation, and it was disposed prevalently in non-controlled dumps. As an alternative to the direct disposal of waste in the ground, thermal treatment or incineration was used. In Italy, the concept of recycling and recovery of materials through separate waste collection began only in the 90s. In this period also laws regulating waste disposal in the dumps were issued. In Italy a legislative measure, which was very important from the point of view of waste disposal, was Legislative Decree n. 22 dated 1997, better known as the “Ronchi Decree”, from the name of the Minister who signed the law. The more important aspect of this decree is that it represented a change in the legislation regarding all the regulations on waste. Practically, the philosophy of the decree is based on the belief that pollution produced by waste must be coped with by decreasing the total amount of waste produced, and not only by the simple disposal of waste in the dumps. At present, the Ronchi Decree has been superseded and cancelled by Legislative Decree n. 152 dated 2006, subsequently followed by Legislative Decree n. 205, dated 3 December 2010 – in force from 25 December 2010 – implementing European Directive 2008/98/EC on waste in the Italian legislation.

European Directive 2008/98/EC

The Directive states how waste must be treated in the Community. The primary aim of the directive is to protect the environment and human health, through the prevention of the negative and dangerous effects deriving from the production and management of waste. According to the directive, a greater protection of the environment requires the realization of a series of measures that are applicable according to an order of priorities: 1) prevention of waste; 2) preparation for waste re-utilization, 3) recycling; 4) another type of recovery (for example of energy), 5) disposal. This means that first of all we need to think of preventing waste, avoiding producing waste; and if this is not possible measures must be taken to reutilize it, after which it must be recycled, and so on...
All the Member States of the European Community can apply further legislative measures in order to strengthen this hierarchy, but what is important is that human health must always be guaranteed, and that the environment must be respected. Whoever produces or possesses waste products must take care of treating the same or must hand it over to someone else who is appointed to do so. In particular stocking and treatment of dangerous waste products must follow an even more severe code for their disposal than domestic waste, to avoid any risks for humans or for the environment. Furthermore, since the production of waste tends to increase in Europe, the regulations carry an invitation to strengthen all measures in the field of prevention and reduction of the correlated impacts and to encourage the recovery of waste.

Ronchi Decree and Legislative Decree 52/2006

The Ronchi Decree defines waste as “any substance or object which the owner discards, or intends or is required to discard”. First of all this definition assumes that any goods are destined, sooner or later, to become waste. Secondly it can be deduced that the transformation from goods to waste depends mainly on the consumers’ choice.
Waste is classified according to its origin, into Municipal Solid Waste (MSW) and Special Waste (SW) and, depending on

its characteristics and dangerous nature, into Dangerous Waste (DW) if the waste contains at least one of the substances listed in the attachments of the Decree, and into Non-Dangerous waste if the waste does not contain any of the said substances. For example, batteries, expired drugs and exhaust oil are considered DW.
If, instead, we look at waste management, we must remember that any treatment will only lead to a transformation of the waste and/or its transfer from a physical state to another, however in no cases does the treatment lead to its destruction (the law on conservation of mass). Therefore the most sustainable behaviour with regard to waste, is to reduce the amount upstream, in other words to produce as little waste as possible trying to use each thing a number of times (as in the past). And these were the principles that were followed when the Decree was written. In order to reach these aims, it is fundamental to inform the citizens and the producers, and make them aware. Wherever it is not possible to reduce the amount upstream, or in case the materials cannot be re-utilized, waste that cannot be recovered must be separated from waste that can be sent for recycling.
Legislative Decree 152 of 2006, became effective on 22 April 2006, and at the same time it also cancelled the Ronchi Decree. Legislative Decree 152 of 2006, regulates waste management, packaging and other special categories, such as electronic waste, hospital waste, etc. The area of application of this Decree regards waste management and reclamation of polluted sites, also in fulfilment of the EEC Directives. The management activity has the task of guaranteeing a high level of protection of the environment and efficient controls, bearing in mind the specific nature of dangerous waste, and also the protection of natural resources. Waste must be recovered or disposed of without any danger for human health and without using processes or methods that could jeopardize the environment. The Decree promotes, as a fundamental point, the prevention and reduction of waste production, and of poisonous waste, in particular through the development of clean technologies, techniques to eliminate dangerous substances in waste with the scope of favouring the recovery of the same; and lastly a decrease in the quantity of waste. Finally, the measures aimed at the recovery of waste by reutilization, recycling of the same or any other direct action, must be oriented mainly at using waste as a source of energy. Among the principal novelties of the Decree, there are measures to increase separate waste collection, which includes a definition of the aims (the target is 65% by 2012).

Waste disposal

Integrated waste management

In compliance with Legislative Decree 152/06, 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.
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. According to the latest ISPRA report, in Italy, landfills still account for 26% of municipal waste produced. Recycling of the various parts coming from sorting or from mechanical biological treatment (MBT) of municipal waste reaches, overall, 44% of production: 18% consists of recovery of the sorted organic part (food waste+garden cuttings) and over 26% of recovery of the other parts. 19% of municipal

waste produced is incinerated, while 2% is sent to manufacturing plants, such as cement plants, power plants, etc., to be used in the production cycle and to produce energy (co-incineration); 1% is used, after adequate treatment, for covering landfills, 3%, consisting of waste resulting from MBT plants, is sent for further treatment, and 1% is exported. Finally, the "other" item includes, for example, the quantity of waste remaining in storage at the end of the year at treatment plants.

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 (only 19% of the waste at present is incinerated), 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 rain water 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

Recycling materials

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. According to the last report by ISPRA, separate waste collection amounted to 14

million tons in 2015 (47.5 % of the total), and the organic fraction was predominant (43.3% of the total), followed by paper (22.5%), glass (12.5%), plastic (8.4%), wood (5%), bulky (3.5%), metals (1.9%), waste electrical and electronic equipment (1.6%), textiles (0.9%), other (0.6%).

Paper

Paper is the material with the highest recycling rate in our country. In fact in 2015 the percentage of paper and cardboard packaging material that was recovered amounted to 88,7% and average per capita collection in Italy was assessed at 51.5 kg/inhabitant. 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. Furthermore, with regard to this material the percentage of recycled glass in Italy is high, equal to 70.9% of the material consumed in the market in 2015, according to the estimates made by Co.Re.Ve., the consortium in charge of glass collection and management. 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 were 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 more simple 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. According to ISPRA, recycling of packaging material amounts to 84.4%. 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. According to ISPRA, in 2015 64.2% of the packaging that is used in the consumer market in Italy was recovered.

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. According to CiAl estimates, in 2015 the recovery of aluminum packaging was 75.5% and the avoided CO2 emissions of 345 thousand tonnes.

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

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.