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ENVIRONMENTAL BENEFITS OF GLASS

(History of glass manufacture, Types, Environmental impacts & Possibility of glass recycling)

Toni Abou Jaoudeh
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I- Towards an integrated solution

Most experts believe that to control the increasing waste disposal problems in any country, an integrated waste management approach should be adopted. An integrated approach to managing waste involves source reduction, reuse, recycling, and then (and only then) either landfilling or incineration as a final disposal method. In other words, the goal is to eliminate as much as possible of the waste stream by either reducing the amount of waste generated in the first place or at least reusing or recycling everything possible.

Source reduction, also called waste reduction, can be accomplished in many ways. Buying in bulk, avoiding disposable products, and buying durable (and repairable) goods are all excellent waste reduction strategies. Industry can help by reducing the size or weight of a product or its packaging.

Reusing is simple once the habit is established e.g. using glass bottles to hold frozen juice.

II- Why recycle?

Human activities are causing serious problems for our planet's environment. The nature cycles are well equipped to handle the waste products of the normal activities of animals and plants. They could cope with human wastes, too, when they were fewer people around. Nevertheless, during the past couple centuries, humans have been multiplying to enormous numbers, and the wastes generated are beginning to pile up in amounts that have no parallel in earth's long history.

Another problem with today's trash is that people have learned to make substances that never existed in nature. Working with the same chemical elements that make up complex natural compounds like proteins or starches, chemists have linked them together in new ways to form versatile new materials like polyethylene or polystyrene plastics. Some of these new materials are stronger, lighter, more durable, or more cheaper than natural products. However, when people throw these unnatural materials away, the natural recycling processes can't deal with them because the decay bacteria can't break chemical bonds.

Collecting the recyclable materials, recycling them and reusing them can save energy, reduce pollution, help to conserve natural resources many of which are in short supply and reduce the waste that has to be thrown anyway. In fact, making goods from recycled materials can help save fuel and means that valuable resources are not being used up unnecessarily. In addition, making goods from recycled materials can also help to reduce the amount of energy needed to produce them. Every ton of glass made from recycled glass cullet saves 30 gallons of oil.

Recycling can help to reduce both pollution and waste. Less waste to be disposed of means fewer landfill sites or less need for incineration. Less demand for raw materials means that fewer habitats will be destroyed by mining, and valuable fuel and resources will be saved. In addition, air and water pollution are also reduced.

III- The basics of recycling

Recycling is reclaiming the useful materials from waste so they can be used again, such as glass, metals, paper, cloth, plastics, and rubber. EPA calls recycling "collecting, reprocessing, marketing, and using materials once considered trash." The same material is used repeatedly to make the same –or an equivalent– product. This cuts the amount of virgin materials required for manufacturing.

Recycling is not a new idea. In nature, many things are recycled repeatedly. In the past, things were made to last and people repaired and reused them, rather than throwing them away. Phoenician boats from the time of the Ancient Greeks have been found laden with glass cullet (broken bits of glass) collected to make new glass objects.

IV- History of glass manufacture

Prehistoric man is known to have used natural glass for arrowheads and simple tools. This glass was created by sudden volcanic eruptions followed by rapid cooling. At about 4000BC the first man-made was produced in the Near East. This was in the form of glazes for coating beads. Hollow glass vessels date to about 1500BC and were made by covering a sand core with a layer of molten glass. When the glass solidified the sand was scooped out, leaving small vessels. Often these vessels were decorated by applying threads of colored glass to the surface and arranging them in attractive patterns.

It was until the 1^{st} century BC that glass vessels, as we know today, made their appearance. It was then that the glass makers realized that glass could be blown into various shapes. The introduction of the blowing iron was probably the most important step in the development of glass manufacture. Due to impure materials used in the early days most glasses were highly colored, when required, by the addition of coloring materials.

This, of course, brings to the days of the Roman Empire and it was at this time that glass was first made in Britain. Needless to say, the science of glass technology did not exist and glass making depended entirely on the skills and closely guarded secrets of individual glass makers especially in Venice (still famous for its glassware today) in. However, the Venetian monopoly was soon broken and glass making spread across Europe and the Islamic countries of the

Near East. Better raw materials were used and more efficient melting furnaces were built. San, which is the main constituents of glass, was in plentiful supply. For flux, ash from local forests plants and trees were used. This contained a high proportion of potash and thus potassium oxide, rather than sodium oxide, was an important constituent. Wood was used for fuel and consequently glassworks were normally situated in forest areas away from towns. Until the 16th century the main product of northern European glass-makers was window glass of various kinds.

There were methods of producing flat glass, and both involved blowing a bubble of glass. In the "crown" method the glass-maker blew a large bubble of glass, which he then spun rapidly, while the glass attached to his blow pipe in the center. The blow pipe was then removed and the disc was annealed. This disc was then cut into panes of different sizes. Obviously the size of the panes was rather limited and hence the small windows in ancient houses. Where the blow pipe was attached there was an attractive "bull's eye" left behind. Panes of glass with a bull's-eye are still in demand for decorative uses.

In the cylinder, or broad glass method, the glass maker blew a bubble, which he then elongated by swinging it in a pit into a cylinder of glass closed at both ends. The ends were then cut-off, the cylinder was cut lengthways, it was re-heated and was then opened out into a flay sheet. It is interesting to note that this method was in use up to the 1930's in Europe and may even be used to day in some underdeveloped countries with a limited demand for window glass.

After the fall of the Roman Empire glass making traditions appeared to have continued around the Mediterranean and the Near East. Venetian glass makers gained a reputation for technical skill and artistic ability, which is still in evidence today. By the 15th century, Venice developed a thriving glass export business but its monopoly did not last forever. In spite of all precautions not to divulge the Venetian secrets, some glass-makers succeeded in escaping and set up glassworks throughout Europe.

As mentioned before, wood was the fuel used and as forests were becoming depleted, wood was becoming scarce. Wood was in demand not only by the glass industry but other industries, notably shipbuilding, were competing for it. This hastened the change to coal-fired furnaces and in 1615 there was a Royal Proclamation forbidding the use of wood for glassmaking. The need for coal and other new materials decided the location of the present glass industry in the areas where these were available.

The next milestone in the history of glass was the invention of lead crystal glass. The establishment of the Royal Society of London in 1660, which had as its objective the promotion of science, played an important part in the history of glass. Several members of the Worshipful Company of Glass Sellers of London, incorporated in 1964, were also members of the Royal Society. The company supported George Ravenscroft in his scientific research into a "particular" sort of "Christaline Glasse resembling Rock Christall". Ravenscroft, attempting to counter the effect of crizzling and clouding caused by the fumes from an excess of alkali from batch, added lead to the raw material and produced a new material which was far superior than the glass used so far in the Venetian composition. The new glass was softer and thus easy to decorate by cutting and grinding, it had a longer working range, enabling the glass-maker to produce more intricate designs and above all it had a higher refractive index giving it more brilliance and beauty. The higher refractive index was invaluable to the optical industry. Thanks to Ravenscroft's invention optical lenses, astronomical telescopes, microscopes, etc., became possible.

The demand for high quality flat glass for large windows, mirrors and coach doors could no longer be satisfied by the existing methods of flat glass manufacture and by the mid-seventeenth century, glass casting was developed. The glass was poured from crucibles into pan-shaped moulds. The surfaces of this glass were uneven and were ground and polished by hand. High quality cast plate glass production was not introduced in Britain until 1773 when the British Cast Plate Glasses Company was formed.

Another English invention was the glass cone. The cone was the glasshouse but was shaped in such a way that it acted as a chimney to remove unpleasant gases and make working conditions considerably more bearable. A few cones dating from the 17th century have been preserved notably.

For 2,000 years, hand blowing glass bottles continued to be the principal way of making glass bottles. However, during the last hundred years or so, mechanized glass blowing techniques have revolutionized the production of glass containers, allowing bottles to be produced quickly and cheaply. At the beginning of the twentieth century, in 1903, the first fully automated bottle making machine was designed and put in operation in Toledo, Ohio in the USA. This development was responsible for a huge increase in the use of glass bottles for packaging.

Today, glass containers are widely used to package a huge array of foods and drinks. In addition, glass manufacturers today make glass bottles that are much lighter than bottles made in previous years. This process, called 'lightweighting', saves considerable amounts of energy and raw materials.

The following developments are worth noting:

1904 First commercial production of fused silica

1927 Beginning of fiber-optics

1947 Introduction of photo-sensitive glass

1957 Development of glass ceramics

Flat glass production underwent equally revolutionary changes and thus in:

1870 Rolled glass produced

1898 Wired glass first made

1910 Mechanical cylinder drawing machine

1913 Sheet glass drawn mechanically by a machine straight from the furnace

1918 Bicheroux process for casting, grinding and polishing of plate glass

1037 Pilkingtons' twin grinding and polishing of plate glass

1959 Float glass

Glass in vacuum science had the following landmarks:

1879 First electric light bulb

1892 Vacuum bottle for liquid gases

1904 Domestic vacuum flask

V- Making glass

A- What is glass?

Glass is a product obtained by the fusion of several inorganic substances, of which normally silica (SiO_2) in the form of sand is the main one. The fused mass is cooled to ambient temperature at a rate fast enough to prevent crystallization, i.e., the molecules cannot arrange themselves into a crystalline pattern. The fast rate of cooling to prevent crystallization applies to transparent glasses, whereas in the case of translucent or opal glasses, the rate of cooling is such as to produce a pre-determined level of Crystal formation.

B- Types of glass

A large variety of glass with different chemical and physical properties can be made by a suitable adjustment to chemical compositions. (Table 1)

1- Commercial glasses

The main constituent of practically all commercial glasses is sand. Sand by itself can be fused to produce glass but the temperature at which this can be achieved is about 1700°C. Adding other chemicals to sand can considerably reduce the temperature of fusion. The addition of sodium carbonate (Na_2CO_3), known as soda ash, in a quantity to produce a fused mixture of 75% silica (SiO_2) and 25% of sodium oxide (Na_2O), will reduce the temperature of fusion to about 800°C. However, a glass of this composition is water soluble and is known as water glass. In order to give the glass stability, other chemicals like calcium oxide (CaO) and magnesium oxide (MgO) are needed. The raw materials used for introducing CaO and MgO are their carbonates $CaCO_3$ (limestone) and $MgCO_3$ (dolomite), which when subjected to high temperatures give off carbon dioxide leaving the oxides in the glass.

Most commercial glasses whether for containers, i.e. bottles and jars, flat glass for windows or for drinking glasses, have somewhat similar chemical compositions of:

70% - 74%	SiO_2 (silica)
12% - 16%	Na_2O (sodium oxide)
5% - 11%	CaO (calcium oxide)
1% - 3%	MgO (magnesium oxide)
1% - 3%	Al_2O_3 (aluminum oxide)

Within these very wide limits the composition is varied to suit a particular products and production method. The raw materials are carefully weighed and thoroughly mixed, as consistency of composition is of utmost importance. To the mixture of chemicals a further raw materials added – broken glass, called cullet. Cullet can come from factory rejects; it can be collected by the public in Bottle Banks or from the bottling industry. Almost any proportion of cullet can be added to the mix (known as batch), provided it is in the right condition, and green glass made from batch containing 95% of cullet is by no means uncommon. Although the glass collected by Bottle Banks may come from several manufacturer, it can be used by one of them, as container glass compositions have been harmonized to make this possible. It is, however, important that glass colors are not mixed and that the cullet is free from impurities, especially metals and ceramics.

Flat glass is similar in composition to container glass except that it contains a higher proportion of magnesium oxide.

2- Other types of glasses

Glasses vary widely in their chemical make-up; indeed, there are very few elements in the periodic table that have not been incorporated in a glass of some kind. However, most of the glasses produced commercially on a large scale may be classified into the three main groups: soda-lime, lead and borosilicate, of which the first is by far the most common.

3- Soda-lime glasses

These are the most common commercial glasses. The chemical and physical properties of soda-lime glasses make them suitable for a visible light and hence applications. The nominally colorless types transmit a very high percentage for a visible light and hence have been used for windows since at least the time of the Romans. Soda-lime glass containers are virtually inert, and so cannot contaminate the contents inside or affect the taste. Their resistance to chemical attack from aqueous solutions is good enough to withstand repeated boiling (as in the case of preserving jars) without any significant changes in the glass surface.

One of the main disadvantages of soda-lime is their relatively high thermal expansion. Silica does not expand very greatly when heated but the addition of soda has a dramatic effect in increasing the expansion rate and, in general, the higher the soda content of a glass, the poorer will be its resistance to sudden changes of temperature (thermal shock). Thus, care is needed when soda-lime containers are filled with hot liquids to prevent breakages due to rapid thermal expansion.

4- Lead glasses

The use of lead oxide instead of calcium oxide, and of potassium oxide instead of all or most of the sodium oxide, gives the type of glass commonly known as lead crystal. The traditional English full lead crystal contains at least 30% lead oxide (PbO) but any glass containing at least 24% PbO can be legitimately described as lead crystal according to the relevant EEC directive. Glasses of the same type, but containing less than 24% PbO, are known simply as crystal glasses, some or all of the lead being replaced in these compositions by varying amounts of the oxides of barium, zinc and potassium. Lead glasses have a high refractive index and relatively soft surface so that they are easy to decorate by grinding, cutting and engraving. The overall effect of cut crystal is the brilliance of the two.

Glasses with even higher lead oxide contents (typically 65%) may be used as radiation shielding glasses because of the well known ability of lead to absorb gamma rays and other forms of harmful radiation.

5- Borosilicate glasses

As the name implies, borosilicate glasses, the third major group, are composed mainly of silica (70-80%) and boric oxide (7-13%) with smaller amounts of the alkalis (sodium and potassium oxides) and aluminum oxide. They are characterized by the relatively low alkali content and consequently have good chemical durability and thermal shock resistance. Thus they are permanently suitable for process plants in the chemical industry, for laboratory apparatus, for ampoules and other pharmaceutical containers, for various high intensity lighting applications and as glass fibers for textile and plastic reinforcement. In the home they are familiar in the form of ovenware and other heat-resisting ware, possibly better known under the trade name of the first glass of this type to be placed on the consumer market– Pyrex.

6- Special glasses

Glasses with specific properties may be devised to meet almost any imaginable requirement, the main restriction normally being the commercial considerations, i.e., whether the potential market is large enough to justify the development and manufacturing costs. For many specialized applications in chemistry, pharmacy, the electrical and electronics industries, optics, the construction and lighting industries, glass, or the comparatively new family of materials known as glass ceramics, may be the only practical material for the engineer to use.

7- Vitreous silica

As mentioned previously, silica glass or vitreous silica is of considerable technical importance. However, the fact that temperature above 1500°C are necessary in the melting makes the transparent variety (often known as fused quartz or quartz glass) expensive and difficult to produce. The less expensive alternative for many applications is fused silica, which is melted at somewhat lower temperatures; in this case small gas bubbles remain in the final product which is therefore not transparent.

Another substitute for vitreous silica can be produced by melting a suitable borosilicate glass and then heating it at around 600°C until it separates into two phases. The alkali-borate phase may be leached out with acids, leaving a 96% silica phase with open pores of controllable size which can be converted into clear glass. Porous glasses of this kind, commonly known as Vycor, may be used as membranes for filtration purposes and certain biological applications.

8- Aluminosilicate glasses

A small, but important group of glasses is that known as aluminosilicate, containing some 20% aluminum oxide (alumina- Al_2O_3) often including calcium oxide, magnesium oxide and boric oxide in relatively small amounts, but with only very small amounts of soda or potash. They tend to require higher melting temperatures than borosilicate glasses and are difficult to work, but have the merit of being able to withstand high temperatures and having good resistance to thermal shock. Typical applications include combustion tubes, gauge glasses for high pressure steam boilers, and in halogen-tungsten lamps capable of operating at temperature as high as 750°C.

9- Alkali-barium silicate glasses

In normal operation, a television produces X-rays which need to be absorbed by the various glass components. This protection is afforded by glasses with minimum amounts of heavy oxides (lead, barium or strontium). Lead glasses are commonly used for the funnel and neck of the tube, while glasses containing barium are usually employed for the face or panel.

10- Borate glasses

There is a range of glasses, containing little or no silica that can be used for soldering glasses, metals or ceramics at relatively low temperatures. When used to solder other glasses, the solder glass needs to be fluid at temperatures (450°- 550°C) well below that at which the glass to be sealed will deform.

Some solder glasses do not crystallize or denitrify during the soldering process and thus the mating surfaces can be reset or separated; these are usually lead borate glasses containing 60-90% PbO with relatively small amounts of silica and alumina to improve the chemical durability. Another group consists of glasses that are converted partly into crystalline materials when the soldering temperature is reached, in which case the joints can be separated only by dissolving the layer of solder by chemical means. Such denitrifying solder glasses are characterized by continuing up to about 25% zinc oxide.

Glasses of a slightly different composition (zinc-silicoborate glasses) may also be used for protecting silicon semi-conductor components against chemical attack and mechanical damage. Such glasses must contain no alkalis (which can influence the semi-conducting properties of the silicon) and should be compatible with silicon in terms of thermal expansion. These materials, known as passivation glasses, have assumed considerable importance with the progress made in microelectronics technology in recent years that has made the concept of the "silicon chip" familiar to all.

11- Phosphate glasses

Most types of glass are good insulators at room temperature, although those with a substantial alkali content may well be good conductors in the molten state. This is because the conductivity depends mainly on the ability of the alkali ions in the glass to migrate in an electric field. However, some glasses that do not contain alkalis conduct electrons which jump from one ion to another. These are known as semi-conducting oxide glasses and are used particularly in the construction of secondary electron multipliers. Typically they consist of mixtures of vanadium pentoxide (V_2O_5) and phosphorous pentoxide (P_2O_5).

12- Chalcogenide glasses

Similar semi conductor effects are also characteristic of a series of glasses which can be made without the presence of oxygen (non-oxide glasses). These may be composed of one or more elements of the sulfur group in the periodic table (called chalcogens, from the Greek word for sulfur) combined with arsenic, antimony, geranium and/or the halide (fluorine, chlorine, bromine, iodine). Some of them have potential use as infra-red transmitting materials and as switching devices in computer memories because their conductivity changes abruptly when particular threshold voltage values are exceeded, but most have extremely low softening points and much poorer chemical durability than more conventional glasses.

13- Glass ceramics

An essential feature of glass structure is that it does not contain crystals. However, by deliberately stimulating crystal growth in appropriate glasses it is possible to produce a range of materials with a controlled amount of crystallization so that they can combine many of the best features of ceramics and glass. Some of these "glass ceramics" formed typically from lithium aluminosilicate glasses, are extremely resistant to thermal stock and have found several applications where this property if important, including cooker hobs, cooking ware, windows for gas or coal fires, mirror substrates for astronomical telescopes and missile nose cones.

14- Some special applications of glass

Different forms and varieties of glass are used in almost every conceivable aspect of human life. Architecture, food and drink, laboratory equipment, instrumentation, the chemical, nuclear and electrical industries, lighting, optics -the list is endless. For some areas of application, one type of glass predominates: for example, soda-lime glass is used almost universally in the building and packaging industries while borosilicate tends to be standard in the chemical processing industry. However, for some purposes a wide range of glasses is required to meet different requirements, as is the case with optical glass, glasses for sealing to metals and glass fibers.

15- Optical glasses

Glasses can be designed to meet almost any specified combination of optical properties of which the most important are the refractive index (representing the deviation of a ray of light striking the glass at an oblique angle) and the dispersion (the dependence of the refractive index on wavelength).

Glasses with high dispersion relative to refractive index are called flint glasses while those with relatively low dispersions are called crown glasses. Typically flint glasses are lead-alkali-silicate compositions whereas crown glasses are soda-lime glasses.

The substitution of other oxides permits considerable variations to be achieved. Thus barium crown (barium borosilicate), barium flint (barium lead silicate), borosilicate crown (sodium borosilicate) and crown flint (calcium lead-silicate) are all widely used. Phosphorous and the rare earth's, especially lanthanum, may also be valuable ingredients in some optical glass compositions. The inclusion of transition elements (copper, titanium, vanadium, chromium, manganese, iron, cobalt or nickel) in glass produces strong absorption bands in the ultra violet part of the spectrum as well as broad bands in the visible and infra-red, enabling a series of color filters and glasses with modified transmission properties in the ultra-violet and infra-red to be produced.

The use of rare earth's has less effect on color but it is of particular significance in the manufacture of laser glasses, most of which contain neodymium. The neodymium ions in the glass, when stimulated emit radiation at a particular wavelength (1.06um) and this is transformed into high-intensity coherent optical data, and for various measurement functions in industry.

A characteristic of some optical glasses is that when they are exposed to ultraviolet or short-wave infra-red radiation (as with sunlight) they become dark, but when removed from such exposure they revert to their original state. These, known as photochromic glasses, include in their composition silver halide crystals produced by adding silver slats and compounds of fluoride, chlorine or bromine (the halides) to the base-glass (normally borosilicate). Controlled thermal treatment during and after melting causes extremely small phase separations to occur and these are responsible for the reversible darkening effect.

16- Sealing glasses

Another application for which a large variety of glass compositions are used is sealing to metals for electrical and electronic components. Here are the available glasses may be grouped according to their thermal expansion which must be matched with the thermal expansions of the respective metals so that sealing is possible without excessive strain being induced by the expansion differences.

For sealing to tungsten, in making incandescent and discharge lamps, borosilicate alkaline earths-aluminous silicate glasses are suitable. Sodium borosilicate glasses may be used for sealing to molybdenum and the iron-nickel-cobalt (Fernico) alloys are frequently employed as a substitute, the amount of sodium oxide permissible depending on the degree of electrical resistance required. With glasses designed to seal to Kovar alloy, relatively high contents of boric oxide (approximately 20%) are needed to keep the transformation temperature low and usually the preferred alkali is potassium oxide to ensure high electrical insulation.

Where the requirement for electrical insulation is paramount, as in many types of vacuum tube and for the encapsulation of diodes, a variety of lead glasses (typical containing between 30% and 60% lead oxide) can be used.

C- Colors

Unless the raw materials are very pure, glass made by mixing and heating sand, soda ash and limestone will normally be green, the depth of the colorants present in the raw materials. A sand containing as little as one-thousandth part of iron oxide will give normal soda-lime glass, used for windows and glass containers, a greenish tint.

For many products, instead of using high purity (and thus expensive) raw materials, glass manufacturers may decolorize the glass by adding minute amounts of other colorants which produce complementary colors to green so that the finished articles appear colorless. Thus selenium (which gives a pink color) and cobalt (which gives blue) can be added to soda-lime glass to offset the effect of the green or yellow due to the iron and this is done in the manufacture of glass containers. Nickel may be used similarly in the decolorizing of lead crystal glass.

Different additions may produce different colored glasses, the range of possible colors being almost infinite. Some of the most frequently used colorants and the colors they produce are listed below. The color depends on the state of oxidation of the colorant, the type of glass in which it is used, and thermal treatment. (Table 2)

The use of large amounts of several different colorants will tend to produce black glasses. Opaque or opal glasses can be produced by the addition of appropriate amounts of fluoride or phosphate compounds, which produce crystal growth, known in the glass industry as devitirification.

D- Glass melting furnaces

There are two types of glass melting furnaces:

1- Pot furnaces

These are structures built of refractory materials in which there is no contact between the furnace and the glass. Glass is melted in several pots made of refractory materials which are resistant to glass attack at high temperatures. The pots are charged with a batch, which is melted over a number of hours and worked on a 24 or 18 hour cycle. An average pot can hold 600-700 Kg of glass. Pot furnaces are used where the glass is formed by hand and mouth blowing. One of the main advantages of this system is that several types of glasses can be melted at the same time. A pot can be used for about 30 melting cycles and thus produce between 18 and 21 tons of glass.

Fuel economy is normally achieved by recuperation, i.e., the pre-heating of combustion air by waste heat from the furnace exhaust gases. In this system the pre-heating of the combustion air is done by passing the air through metal tubes on the outside of which the exhaust gases flow towards the chimney. Thus the heat exchange is continuous. Electricity can also be used for melting.

2- Tank furnaces

These are used where continuous flow of glass is needed to feed automatic glass forming machines. They are more economical in their use of fuel and are used mainly for the large scale production of containers, flat glass, electric bulbs, tubing and domestic machine made tableware. A large float glass furnace can have a capacity of 2,000 tons.

A tank furnace consists of a bath, built of a very special high refractory material, which can resist chemical attack of molten glass at temperatures in excess of 1500°C and a superstructure where combustion takes place. The quality of refractory materials, used for building the bath, has improved to such an extent that whereas some 30 years ago, the life of a furnace was well below 2 years, it is now over 9 years.

In order to achieve high melting temperatures and fuel economy, a regenerative or recuperative system is used. Both these systems utilize the waste heat of combustion for pre-heating the incoming combustion air.

While in the recuperative system the heat exchange between the combustion air and waste gases is continuous, in the regenerative system the waste gases are passed through a large chamber packed with refractory bricks arranged in a pattern which permits free flow of the gases. The brickwork is heated by the waste gases and after having been heated for some 20 minutes, the direction of firing is reversed. Combustion air is passed through the chamber and the heat thus collected in the brickwork is used for pre-heating the combustion air. The firing is thus from right to left, normally for 20 minutes, during which time the right hand generator is heated and so there is a reversal of firing every 20 minutes. The cycle time can be changed for best heat exchange results and modern furnaces have computer managed control systems, which adjust the time of firing in each direction to achieve the best heat exchange conditions.

Heavy fuel oil or natural gas is normally used for firing tank furnaces. Glass, being an electrical conductor at high temperature, can also be melted by electricity. However, electricity is far too expensive and is normally used to boost the output from a gas or oil fired furnace. Nevertheless, technological progress in electric melting has enabled the use of all electric glass melting furnaces even at the high cost of electricity.

E- Glass forming processes

Container glassware is made by first melting a mixture of materials in a furnace. Sand (SiO_2) is the main ingredient but very high temperatures would be needed to melt the sand alone. To get a lower melting temperature, a fluxing agent is added. This could be any alkali, but in practice sodium carbonate (Na_2CO_3) known as soda ash is used. To obtain a durable glass, it is also necessary to include a stabilizer and calcium carbonate ($CaCO_3$) or limestone as is normally used. Added to this mixture is a final ingredient - cullet. Cullet is the term for used, crushed glass from bottle banks and factory breakages. Modern furnaces can make glass using up 90% cullet. Cullet melts at a much lower temperature than the raw materials. Other ingredients are used in small amounts, the proportions of each depending on the type of glass required.

Using cullet:

- Prevents disfigurement of the country side caused by quarrying.
- Saves 30 gallons of oil per ton of cullet added.
- Saves 1.2 tons of raw materials per ton of cullet used.
- Reduces air pollution by up to 20% and water consumption by up to 50%.

To make glass containers the mix of ingredients, known as batch, is fed continuously into furnaces and melted at about 1,500°C. The molten glass from the furnaces is then cooled in a channel leading away from the furnace, until it is the right consistency for bottle and jar making. The glass now the stiffness of syrup is forced through holes in the channel by a machine that accurately controls the size and shape of glass gobs. These gobs then pass through cast iron moulds where compressed air forces the glass to take up the shape of the mould. A careful check is made on every bottle and jar at this stage both by test machines and manually. The new glass bottles and jars, each containing a percentage of previously waste glass, are now ready to be filled and distributed to retail outlets.

2.5 million tons of glass bottles and jars are purchased every year. Although more people are recycling, many tons of bottles and jars still end up in landfill. Glass makes up between 8% - 10% by weight of the household refuse. Glass does not rot. It is virtually indestructible and will remain in the ground forever.

F- Secondary glass processing

1- Annealing

Glass like most other materials, contracts on cooling. However, due to its low thermal conductivity, it does not cool uniformly and the surfaces, which cool more rapidly, shrink more quickly than the center. This produces uncontrolled strain in the article. If the internal surface of an unannealed container is scratched, the container will disintegrate. Badly annealed glass articles cannot withstand thermal shock and are liable to break in use. The excessive strain can be avoided by slow cooling at a controlled rate, called annealing. Annealing is done in an oven, called a lehr, through which glass articles pass on a slowly moving conveyor belt.

A container, for example, would enter a lehr at approximately 450°C. as the conveyor moves through the lehr, which is approximately 20m long, the temperature is at first increased to about 560°C, at which the glass just begins to flow and is then gradually reduced to a temperature at which no further strain can be induced, and then cooled by fan air to room temperature. The time required for this process depends on the size of the article and the wall thickness but is normally completed in less than an hour.

2- Toughening

Glass has an extremely high compressive strength and therefore when it does so due to induced tension on the surface. Glass can be thermally strengthened by inducing invisible thin layers in compression on the outer surfaces. In order to break such toughened or tempered glass, the compression has to be neutralized and additional tension applied. Toughening is obtained by re-heating the glass article uniformly to a temperature just above that at which deformation could take place and then rapidly cooling the surfaces by jets of air. If one can imagine a sheet of glass as consisting of 3 layers then the process becomes easier to understand. The air jets rapidly cool and freeze solid the outer layers while the inner layers continues to contract. While it is contracting it exerts compression on the outer layers while putting itself under tension. This method can be applied to flat glass or simple shapes like curved car windscreens or even tumblers. Glass thickness must be uniform, not too thin, and the shape of the article must be such that all surfaces can be uniformly cooled at the same time. Bottles do not satisfy these conditions and cannot be toughened in this way. However, it is possible to toughen bottles chemically by immersing hot bottles in a molten potassium salt. Potassium ions replace sodium ions on the surface and, being larger, create a very thin layer of compression.

Toughened glass cannot be further processed since any damage to the surface will expose the center layer, which is in tension, and the glass will shatter. The shattering of a car windscreen is a good example of this phenomenon.

3- Coating

The coating of glass surfaces has been practiced for centuries. Mirrors are a good example of this art. However, this method of giving glass new physical, chemical and optical properties has made great strides in the last few decades. Lightweight glass containers are coated with organic compounds to give the surfaces a degree of fubricity and thus preventing abrasion in handling. This adds strength to the container and has enabled glass manufacturers to make a lighter and better product. Coating containers with tin compounds also produces a strong product. Coating glass containers with plastic materials for added strength and safety is a further way of lightweighting or increasing internal pressure resistance. Other forms of decorations are etching with hydrofluoric acid, sandblasting and vitreous enameling. In the latter, vitreous enamels, which are low melting point glasses held in an aqueous medium are deposited on the glass through very fine wire mesh screens and are then fired in an enameling furnace. The enamel thus becomes an integral part of the glass article.

4- Decorating

Formed and annealed glass may be further processed. This may be done by taking away from or adding to the surface of the glass. It may also be heated, manipulated, and reshaped. These methods include:

a- Taking away

A disturbance of the surface of glass may result in a matt or obscured finish. Where a transparent surface is then required this is produced by polishing on felt or wood wheels of by hydrofluoric solution.

b- Adding

Vitreous enamels, which are glasses that melt at relatively low temperature and can be colored, may be applied to the surface of formed glass. Metal compounds can also be applied.

In both these cases the article is then reheated after application of the enamel or metal coating so that it fuses permanently to the surface of the glass. Also metal films can be applied by spraying, or by chemical or vapor deposition; and

c- Manipulating

Glass which has been formed and annealed may be reheated and manipulated into a new shape. It then has to be re-annealed and may be toughened.

G- The future of glass

Glass as a material in its own right will always exist. However, many new applications and manufacturing processes will involve glass in combination with other materials. Optical fibers, for example, are currently manufactured with one or more different coating, which are often plastics. With the increasing sophistication of opto-electronic devices, there is an increasing need to combine optical and electronic devices for many applications such as transmission of audio, video and data information. Glasses and ceramics, either alone or composite with other materials, will find increasing application in biological and medical areas. Materials such as photochromic, electrochromic and thermochromic glasses, which respond to external stimuli, are being developed with various, sometimes unusual, applications.

VI- Recycling glass

Glass recycling was one of the firsts of the now widespread initiatives for materials recycling around the world. There is some question as to whether glass recycling was first promoted on environmental grounds, or as a protection measure by an industry which saw markets disappearing to the new lightweight, unbreakable plastic bottles. Despite that, the recyclability of glass is firmly fixed in everyone's mind.

A- Bottles and jars

Glass is 100% recycled. Bottles and jars can be melted down and turned into new containers in a true example of closed-loop recycling. No other ingredients are needed: for each ton of glass returned to a recycling plant, one ton of glass can be produced. Glass never deteriorates, either: it can be recycled endlessly.

Glass is very popular for food and beverage packaging because of its many useful qualities. It is impermeable, transparent, and sanitary. A glass container also generally costs less than containers made from plastic, paper, or metal. For these reasons, the market for post-consumer glass has traditionally been quite steady, and glass has developed into one of the most commonly recycled materials.

Clear glass is made by taking almost pure silica sand and melting it in huge furnaces with some burnt lime or limestone and soda ash. Crushed glass, called "cullet", is usually added to some extent. In addition to clear glass (what the industry calls flint glass), glass commonly comes in brown and green. Colored glass is made by adding small amounts of metals or salts.

B- Other types of glass

Apart from the bottles and jars used for beverage and food packaging, there are many other types of glass products. Because of their various make-ups, however, most are not easily recyclable. Mirrors, drinking glasses, windows, Pyrex, and light bulbs should not be included in the recycling process because they are made of different kinds of glass and cannot be treated the same way.

VII- End products from recycled glass

Approximately 25 to 30% of manufactured glass are made from recycled glass, which means that the average glass container bought at a store has about that much recycled content. When glass isn't made into new glass through closed-loop recycling, it can be used in other ways. This is often the case with glass that is for one reason or another unacceptable to glass manufacturers. Broken glass of mixed colors is an example. This glass can be used in the production of fiberglass and reflective beading and as a substitute for stone in glasphalt. Mixed-color cullet can also be used to make green glass.

VIII- Obstacles

Contamination is one of the biggest problems of the glass recycling industry. A related problem is obtaining a constant supply of high quality cullet. Manufacturers can always obtain a certain amount, but because of color mixes and contamination they can never be sure of their supply of high-quality cullet.

The furnaces used to melt the glass have to be set at different levels according to the percentage of recycled cullet used. To avoid adjusting the furnaces daily, many manufacturers settle on a slightly lower percentage of recycled cullet than they have available to ensure that they can always get the same percentage. So although manufacturers sometimes have up to 70 or 80% good cullet to work with, the average is still down at 25 or 30% because that is the amount they can count on.

Increasing the supply of good quality cullet is a matter of education and improved quality control. From individuals who put out their recyclables for curbside pickup to the managers of collection centers, everyone must learn to handle and prepare the glass containers properly, thus ensuring a constant supply of high-quality cullet. Moreover, current research on automated color sorting and contaminant-detecting equipment should improve the situation. At present, all quality control is done by hand.

Better quality control and more consistent levels of good-quality cullet will allow the percentage of recycled glass on the market to increase. The glass industry is very much in favor of using recycled cullet instead of virgin materials to produce its glass. It is in its economic interest: cullet costs roughly the same as the equivalent in raw materials, but the cullet saves them energy and wear and tear on the furnaces. It is simply a matter of supplying the glass industry with a constant supply of high-quality materials. However, the glass commodities market fluctuates frequently.

IX- How to prepare glass for recycling

Certain steps should be followed before recycling glass. These are simple things to do, but they play an important role in ensuring the quality of the recycled product.

A- Collection of glass

Only glass containers can be recycled: soda, beer, wine, and liquor bottles, as well as juice and food containers. Glass types that cannot be recycled include:

- Broken window glass and broken windscreen glass.
- Heat treated glass e.g. Corning ware, Pyrex or Vision Ware.
- Light globes.
- White opaque bottles (can't see through them).
- Laboratory and medical glass.

A community must develop a collection system that suits its particular situation, taking into account such variables as demographics and local markets for recyclables. Clearly, rural communities are not suited to the same sort of collection methods that would best serve urban areas. Likewise, if a city consists mainly of multifamily buildings, it may need a different system than a community in which single-family dwellings are the norm. In any case, the program must be convenient for the residents ad economically feasible for the community. Separating trash and recyclables is not difficult once the pattern is established: the Glass Packaging Institute estimates that it takes only fifteen minutes per week.

1- Curbside programs

Curbside collection of recyclable materials is the most effective method of residential recycling because it is the most convenient for consumers. In fact, the very idea behind curbside collection is just that: to make it as easy for residents to recycle as it is to throw the materials away.

In a typical curbside program, recyclables are picked up just like the regular household garbage: in their own containers at the curb. Both one-bin and multi-bin systems are used. In the former case, residents do not separate the recyclables themselves but put them all in one bin at the curb; in the latter, residents typically separate their waste into aluminum, glass, plastic, and paper (or some combination of these, depending on the program) and have a container for each at the curb. There are benefits to each of these systems, and it is up to each community to decide which approach works best.

A curbside program is more likely to succeed if collection is scheduled for the same day as regular garbage pickup. This practice eliminates any confusion and allows recycling to become part of an established routine.

Curbside collection is also the most expensive method of collecting recyclables from residential areas. In fact, in its July 1990 issue, *Biocycle* magazine cited estimates that the cost is running at almost $2 per household per month.

2- Drop-off sites

Drop-off centers are the most common method of recycling in the United States. They are the traditional method employed by rural communities, where the housing situation makes curbside collection less practical. It is also the ideal collection method to use in a pilot recycling project, where a community has never engaged in recycling collection before. Recycling drop-off sites are situated at specific locations around a community and supplied with large containers, usually "igloos", trailers, or large waste bins, clearly marked for the kind of materials they accept. They may be located anywhere with enough space to take the large collection containers, such as the corner of a parking lot or an abandoned lot. Such sites can be run by a public body, privately, or by some combination of the two.

Communities using the drop-off system save the expenses associated with curbside collection. Collection costs are nil because the residents bring their own recyclables to the central site, and virtually no personnel are required as the sites can often be left unstaffed. The only costs involved are for the containers to hold the recyclables and for the transport of materials form the drop-off sites to the processor, but even these costs may be paid by the recycler or broker who eventually take the materials for processing.

There are three basic drawbacks of a drop-off recycling system: it relies solely on the voluntary participation of the community. In addition, it requires residents to save up their recyclables and then transport them to the drop-off center. Moreover, with the prices paid for some recyclable materials today, drop-off centers must be secured to avoid theft. To be successful, a drop-off collection facility must keep the public aware of its location, its hours of operation, and the materials it will accept.

3- Buy-back centers

A buy-back center is just what its name implies: a place where the public can take recyclables and be paid for them. Buy-back centers, unlike drop-off sites, are not so often limited to rural locations. They may be found in both rural and urban areas. Even if a community has a curbside pickup program, there are probably one or more buy-back centers somewhere nearby also.

There are several differences between a drop-off center and a buy-back center other than just the matter of payment. The two approaches to recycling may differ in the types of recyclable materials they will accept, their location, the level of communication they will accept, and their hours of operation.

Prices will vary according to the current markets for the recyclable materials turned in.

The location of a buy back center will probably not be quite as convenient as that of a drop-off center. This is true for a couple of reasons. First, people will generally go farther out of their way to return materials if they are earning money for them. Second, buy-back centers often need their own lot or yard because they take up more space with storage, equipment, and machinery and because a shopping center is less likely to allow them to locate on their premises if they are making a profit from their collection.

Moreover, a buy-back center is usually more careful about contaminants. It will probably require all recyclables to be separated and insist that all contaminants be removed. Because the buy-back center is paying you for the materials, it will not pay for the materials it cannot ultimately sell to its end users.

Because buy-back centers must be staffed, they usually have limited hours in comparison to a drop-off location.

B- Cleaning

Glass bottles and jars need to be rinsed and cleaned before being recycled so that all the materials are clean and all contaminants are removed.

C- Sorting

Color separation ensures that the manufacturers can match the color of newly manufactured glass with previous batches. This guarantees their customers a standard color for their products. At recycling centers, one will always find separate facilities for different colored glass. The large centers on supermarket sites usually have a big skip with separate compartments for green, brown and clear colored glass. On the smaller sites there will be three wheeled bins for the same purpose.

It is very important to separate the different colors in a bottle bank because each glass furnace is used to melt a particular color. If green cullet is put in with clear glass for example, it would discolor the new clear glass products. Green and brown glass also have different chemical compositions. There are no economically viable markets for glass of mixed colors in this country.

Customer preference, technical requirements and tradition determine which color is used. Some products look more appetizing in clear containers; others, whose flavors or quality can be affected by light, need the protection of a darker color. For example, the taste of beer changes on exposure to light therefore the beer bottles are of amber colors that allow only certain transmission of light.

Marketing decisions also dictate colors of glass on new packaging. There is currently a trend towards packaging drinks in blue bottles which certainly helps the product stand out on the supermarket shelf but does not fit into the established green, clear or brown trinity. While there are still relatively few blue bottles being produced, they can be banked with green glass, as the small percentages mean the end color will not be affected.

Color separation can be done in the household, at a drop-off center, or at an intermediate processing center or recycling facility. Glass containers could be sorted manually into clear, amber and green glass.

D- Separation

Containers of different colored glass are then taken to a beneficiation plant to upgrade the quality of the waste glass before reprocessing. At these plants, contaminants such as metals, plastic, china, ceramics, and stones are removed, and the glass is crushed. This step is very important since glassworks make high demands on the percentage purity of recycled material because even the smallest amount of contamination or off-colors causes considerable quality losses of the finished glass and incurs costly damages of the production plant (especially of melting ends). In fact, these materials do not melt at the same temperature as the glass does, so they remain in the glass and can damage the furnaces in addition to appearing in the finished product. Moreover, smallest inclusions of silicon crystals, ceramics-, stone or porcelain particles in the finished glass lead to high reject rates caused by fracture. Only a minimum portion of ferrous metals or off-colors cause color-changings in the end product and can in turn cause losses of a days production. For instance, if there is a green glass – quota of only 0.4% in a white glass found, it can never again be discolored chemically. Mainly lead is responsible for selective corrosion at the bottom of melting ends and leads to short circuits if the melting furnace is heated electrically. There are different separators for the different kinds of impurities:

1- All Metal separator

The All Metal separator is used to automatically remove all kinds of ferrous metals from a size of only 1 mm upwards. In the recycling concept of S+S it often is the first cleaning step in the primary stage of machining. It can be also used in the secondary stage for fine separation or to reduce loss of glass.

2- CSP-Separator

The CSP-Separator reliably separates all kinds of non-transparent contamination in the cullets like ceramics, stones or porcelain from a size of 4 mm upwards. In the glass recycling process it can be integrated in the primary stage of machining, either as first cleaning step or as a second cleaning step. Devices With smaller working width are used in the secondary stage for post-purification or to reduce glass losses.

3- All Metal CSP separator

The All metal CSP separator separates all kinds of metals (iron and non-iron metals) and non-transparent contamination simultaneously, for example ceramics, stones or porcelain. This space-saving universal device is installed in the primary stage, usually behind the CSP-Diverter. It can also be a component in the secondary stage contributing to the separation of very fine contaminants.

4- Off-colors separator

This separator is used to remove all kinds of off-colors from the cullets fully automatically. The main field of application is the separation of green and brown glass fragments from white glass to avoid losses in quality. Contaminated white glass can not be discolored chemically, even if there are only slight impurities. This separator is also very significant when separating green off colors from brown glass. Additionally, due to its laser-detection-principle it works as a fine separator for non-transparent contaminants, since it is always used as the last separation stage in the S+S recycling concept.

5- Quality control system

With the Quality control system, the purity of the recycled glass can be analyzed and recorded automatically. It is used in the following areas:

- Inspection of incoming goods in glassworks: fast and accurate quality control of the delivered glass cullets through immediate evaluation of random samples.
- Final inspection of outgoing recycled glass: continuous online-quality-control of the cullets at the end of the recycling process.

X- The mechanics of recycling glass

When collection agents deliver the glass to recycling plant, it is color-separated (if it did not arrive this way) and crushed into cullet: small, uniform pieces about the size of a pea. In some cases, the collection agent will crush the glass into cullet first and deliver the glass already broken to the plant.

The cullet is run through different machines to remove metals and plastic or paper labels. Then it is melted down in huge furnaces and poured into molds to produce clean glass for new bottles and jars.

Two methods are currently being tested for mechanically separating glass by color. Optical sorting tries to compare light reflected from each piece of glass with light reflected from standard pieces of each target color. Magnetic sorting tries to sort clear from colored glass by the iron compounds found in colored glass. These methods have not been developed well enough yet to use on a commercial basis, but their eventual inclusion in the recycling process should make glass recycling even more profitable.

XI- Andela Pulverizer system

Andela pulverizer system reduces glass and many other frangible products, to "friendly sand sized material" which has no cutting edges. It will separate it from most other non-frangible material and discharge them at different points. Capacities are available from 1 ton to 20 tons per hour. It is unique in its ability to pulverize all types of glass, from containers to ceramics, with no need to sort colors, remove labels, plastic or metal caps. The system produces a distinctly different product – a rounded glass particle, less than 3/8" in size, which is easy to handle.

The Andela pulverizer system includes:

- Metering Surge Hopper
- Glass pulverizer
- Trommel separator
- Pulverizer infeed conveyor
- Trommel infeed conveyor
- Optional glass breaker for volume reduction

<u>Cost benefit analysis for Total Glass Recycling</u>

A cost benefit analysis of glass recycling should start with a determination of the revenue associated with the collection of glass. Whatever public or private entity that picks up or accepts the glass from the consumer should have some revenue set aside to finance this service. The money allocated is a revenue or income and the public or private recycler must retain by minimizing all costs. They can keep the collection or tipping revenue and not lose it through labor, transportation or disposal costs.

It is possible to realize a positive revenue every day through glass processing by incorporating both color sortation or closed loop recycling, and the pulverization of glass for open loop recycling. This will result in all the glass being recycled and eliminate all disposal costs for glass.

This analysis is valid for open and closed loop glass recycling. (Appendix A)

XII- Economic analysis

Glass recycling can be incorporated into residential and commercial/industrial recycling programs with minimal additional capital costs. The same collection containers used for curbside collection of residential recyclables can be used for glass collection. Dedicated collection containers could be purchased for offices or other commercial/industrial areas to increase glass recovery from the commercial/industrial waste stream. Operating costs for recycling glass would include labor costs for a coordinating/monitor, collection costs (if applicable), materials handling costs (e.g. separation of glass by color), and transportation costs to deliver the material if pick up service is not arranged with the contractor. These operating costs are usually offset by savings incurred from reduced landfill disposal fees and revenue from the sale of the glass.

Market prices for glass are currently $0 to $15/ton from local recycling centers, based on recent surveys in selected regions. A higher market price could be obtained if good quality glass is consistently delivered or the glass is delivered directly to a glass processing facility. The recycling program presented below is dedicated only to glass recycling. The long payout period for this example is primarily a function of the market price for glass. Glass recycling will be more cost effective if incorporated into an existing program that also includes steel and aluminum recycling.

Assumptions

- Medium scale glass collection program: 1 ton/month
- Purchase of 40 curbside recycling containers: $ 15/container
- Purchase of one large collection bin: $ 500
- Labor for collection/separation of glass containers: 1 hr/week
- Landfill Fee: $ 25/hr
- Labor rate: $ 30/hr
- Transportation cost to recycle center: $ 50/month
- Transportation cost to landfill: $ 150/month
- Recycled glass market price: $15/ton

Economic Analysis Summary (Table 3)

- Annual savings for Glass recycling $ 120
- Capital cost for diversion Equipment/Process: $ 1,100
- Payback Period for investment in Equipment/Process: < 10 years

XIII- Overcoming the barriers to glass recycling

To expand glass recycling, the view of glass in the municipal waste stream should be changed from waste to valuable resource. Strategies should be implemented to separate and collect glass from the waste stream and develop capacity to process, store and market post-consumer glass. The relatively small amount of glass in the waste stream, as compared with paper and organic materials, makes glass a manageable first material to study when developing markets for recyclable materials. There are some recommendations that could be implemented to help the glass recycling industry flourish:

- There is a need for a steady source of funding for recycling efforts. In particular, there is a need for a government level position to facilitate the development of glass recycling throughout the country.
- A strong education campaign focusing on glass recycling needs to be conducted to educate the public and businesses about the need to recycle

glass and the availability of local markets for glass. To this end, existing agencies and organizations should be encouraged to focus their recycling efforts. It is not effective to say we should recycle in a broad and general sense because of the unique requirements of different recyclable materials.

- Government efforts should be focused on glasphalt and higher value end-uses of glass to help diversify markets and maximize returns to the local economy.
- Government should encourage the development of the recycling industry by restoring funding to the Ministry of Environment to assist existing companies wishing to expand their capacity, assist new companies entering the market, and target other companies – especially in manufacturing – to switch to the use of recycled materials. In addition, increased efforts should be placed on developing private-public collaboration.
- There is a need to develop the capacity to expand the range of end-users for recyclable materials such as glass. Community college and local universities should develop courses and projects targeted at developing products made from recycled materials. Some of these students could be encouraged to start their own companies, with some government assistance.

XIV- Safety and health

Precautions must be taken when handling glass. Safety gear such as heavy gloves, long sleeves, boots, and eye protection should be worn to protect handlers from broken and flying glass shards.

XV- Environmental importance of glass recycling

Recycling saves resources, saves money (it cuts down the amount of trash that must be disposed of and turns part of the waste into a valuable resource that can be sold to manufacturer. In many cases it costs less to produce new goods from recycled materials than it does to produce them from virgin raw materials.) and it is kinder to the environment (recycling cuts down the amount of trash that would have to be burned, producing forms of pollution that might escape into the environment). Recycling is easy and provides immediate results.

A- Environmental benefits

Everything people do and don't do affect the land, air and water. Recycling allows to conserve the precious natural resources and energy, contributes significantly to a reduction in pollution, and eliminates the negative environmental impact of alternative disposal methods such as landfilling and incineration. In fact, most landfill built lack safety standards and they are not equipped to stop toxic leachate from seeping into the ground. Moreover, According to Environmental Action, "Even with pollution controls, incinerators are the largest new source of air pollution in most communities. They spew out gases that contribute to acid rain, toxic heavy metals, and dioxins. And incinerators produce millions of tons of toxic ash, which still have to go to landfills". It also helps to preserve treasured wildlife habits and vital ecosystems.

The conservation of natural resources is certainly one of the most compelling reasons to recycle. Most of the products used daily are manufactured from extracted virgin materials. However, by recycling paper products, glass, metals, aluminum, yard wastes, and many other materials, the demand for raw materials to produce the goods consumed can be reduced significantly. In fact, recycling glass uses fewer natural resources, because silica, soda ash, and limestone, the main raw ingredients in glass, do not have to be added again when recycled glass is used. Using a ton of crushed glass in the manufacturing process can save 1.2 tons of raw materials.

Recycling results in significant savings in other areas as well: energy, water, raw materials, and capital can all be saved by reusing what was already produced.

Recycling saves enormous amounts of the precious energy and the fuels which go to produce that energy because manufacturing new products from secondary, as opposed to raw, materials is typically more efficient. The waste stream is a huge source of untapped energy that sadly, when recycling doesn't happen, literally goes to waste. Recycling glass reduces energy use by up to 32%. For instance, recycling one ton of glass saves about nine gallons of fuel oil. In addition, recycling one glass bottle saves enough energy to light a 100-watt bulb for four hours. Furthermore it is quick process: a study done by the EPA showed that the total time used by a householder is only 73 minutes per month. That is a little over two minutes per day.

When recycled materials are used in the manufacturing process instead of virgin materials, there is usually a significant reduction of harmful emissions. Both air and water pollution can be significantly reduced. In fact, by recycling glass air pollution is reduced by 20%. Moreover, a ton of glass produced from raw materials creates 384 pounds of mining waste. Using 50% recycled glass cuts it by about 75%.

The water is affected in much the same way. Factories using raw materials pollute streams and rivers into which they dump their waste more than factories using recyclables. Water use is reduced by 50% by glass recycling.

Apart from the positive reasons for recycling, other incentives stem from the negative environmental impact of alternative disposal methods. Anything that is not recycled will probably finds its way to an incinerator or a landfill. There are significant concerns about air pollution from incinerators that burn municipal solid waste, Much of which could have been kept out and reused. Likewise, both ground and water pollution is caused when landfills leak - which older ones tend to do with frightening regularity.

Continuous reliance on landfills without the serious development of safe alternatives such as recycling simply exacerbates the problem of the shrinking availability of landfill space.

Experts estimate that up to 80% of the household waste stream can be recycled. Fully comprehensive recycling programs can eliminate the need for expensive and harmful incinerators and greatly reduce the reliance on the ever-shrinking supply of landfill space.

B- Social and economic benefits

Recycling programs, being labor incentive, also provide jobs in the community and can help stimulate local economies. The collection, processing and marketing of recyclables all require workers. Curbside collection requires drivers and collectors.

C- Benefits to industry

Business and industry both realize concrete benefits from recycling. For the manufacturing industries, avoided disposal costs, savings from lower energy bills, and avoided costs for pollution control equipment can add up to big savings, which are directly related to the company's profits.

Not only manufacturing companies see cost savings. Companies that institute a comprehensive office recycling program can save thousands of dollars each year in avoided disposal costs. Selling the collected recyclables also contributes positively to the balance sheet. For example, the Boeing Corporation has saved millions of dollars by recycling.

XVI- Public awareness

Recycling is important, but it is not the only way in which we can help to reduce the amount of waste we produce. It is also important to avoid unnecessary waste in the first place, by thinking about what to buy, and avoiding items that have a lot of unnecessary packaging. Buying goods made from recycled materials is also vital as this helps to create markets for recycled products. Buying goods that have been built to last is economical since the items will not have to be replaced so often, and there is a saving on resources. Listed below are some tips that people can implement to help solve the solid waste disposal problem:

- Begin by understanding the value of the waste which you put in your dustbin.
- Develop a recycling mentality. Segregate your household rubbish into glass, newspaper, aluminum cans, plastics. Keep old engine oil in separate containers.
- Bring to the nearest collection point in your area.
- If there is no collection point, help set up one through a local community or other voluntary group. Recycling banks or resource recovery centers for the collection of a number of materials, e.g. glass, paper, cans, and textiles, are feasible and desirable.
- Seek the cooperation of your local authority.
- Draw up a directory of locations for recycling materials in your area and distribute it widely.
- Campaign for the economical packaging of goods.
- Encourage your neighbors and friends to recycle.
- Bring your own bags to shops instead of getting new ones each time.
- Refuse a bag when all that is needed is a receipt.

- Refuse to choose what you cannot reuse. Returnable containers are preferable and should be returned promptly.
- Try to create a market for recycled products by buying them where possible, in preference to those made from raw materials. Where there is none available, ask for them.
- Buy things whenever possible that are well made, long lasting and repairable.
- Pass on things you don't need.
- Buy second hand.
- Give waste food to birds and pets.
- Use waste food for compost.

APPENDIX A

Tables 1,2,3

%
71
16
9
1
3

%
3
1
1

Thermometer Tubing	Thermal stability over a wide temperature range, retaining transparency.	Automatic or hand drawing.	Soda-lime silica. Borosilicate. Lead glass. Depending on temperature range required.
Laboratory Glassware	High chemical durability. Low thermal expansion.	Lamp working (made from tubing by heating and skilful manipulation). Mouth and automatic blowing. Sintering.	Mainly Borosilicate or fused silica for extra low expansion coefficient.
Full Lead Crystal Domestic Glassware	Extra suitable for artistic hand shaping and mouth blowing. Brilliant finish, attractive when full or empty. Comparatively soft-easy to cut and polish or engrave.	Hand made by skilled craftsmen.	Lead glass Approximate composition: % SiO2 3 PbO 1 K2O 1
Heat Resistant Oven to Table Ware	Resistant to thermal shock. Attractive. Easy to clean. Can be used in microwave ovens.	Automatically pressed or blown.	Borosilicate glass Approximate composition: % % SiO2 80 Na2O 4.5 B2O3 12 Al2O3 5
Optical Glass	A wide range of refractive indices. Wide range of dispersion coefficients. Perfect homogeneity. Complete transparency.	Extrusion and pressing, then ground and polishing.	While range of compositions. Depends on application.
Electrical components: cathode-ray	Good dielectric properties. Low electric losses	Blowing. Drawing – in rod form and in	Wide range of compositions

tubes, capacitors and resistors, computer components, printed circuits.	over a wide range of temperatures. High operating temperatures.	sheets. Sintering and Pressing – glass is ground to fine grains and then is subsequently pressed into required shape and then fired.	
Glass Building Blocks	Resistant to normal temperature changes. Resistant to atmospheric conditions. Mechanical strength. Attractive. Translucent.	Automatic pressing – pressed in halves and then fused together.	Soda-lime silica glass. Similar to flat glass.
Ballotini: minute glass sheres (1-60 microns) which reflect light		Flame drawing – velocity of flames draws particles of glass up tower and as the softened glass falls on the outside, spheres are formed by surface tension effects.	Soda-lime silica glass. Similar to flat glass
Glass Fiber	High strength-to-weight ratio. Resistant to attack by corrosive substances. Resistant to high temperature. Flame resistant. High electrical resistance.	Filament drawing. Continuous filament. White wool. Crown process. Can be woven into textiles or incorporated with plastics to form insulating materials, hulls…	Soda lime silica and where resistance to weathering is necessary, a borosilicate glass is used, e.g. Soda-lime silica glass % % SiO_2 54.5 B_2O_3 8.3 Al_2O_3 14.5 Na_2O 0.5 CaO 22.0

Lighting Glassware 1- Electric light bulb	Economical to produce. Easy to manufacture by mass production methods. Resistant to shock. Impermeable and inert to gas, vapor and liquid. Durable. Transparent or translucent.	Ribbon machine – produces bulb at the rate of over 1,000 per minute. This machine also produces blanks used in the manufacture of vacuum flasks.	Soda lime silica glass % SiO_2 72.5 Al_2O_3 1.3 CaO 6.5 MgO 3.0 Na_2O 15.9 K_2O 0.3
2- Special Glasses High pressure mercury vapor lamps b- Aircraft fire-warning sensors c- Glass for encapsulating electric components.	Low electrical conductivity. Resistance to intense chemical activity of mercury vapor. Low melting point. High electricity conductivity.	Special glasses can be formed by using manufacturing processes, or, in some cases laminated onto ordinary glasses i.e. sodium discharge lamps.	Wide range of compositions.
3- Tubing for fluorescent lighting	Low electrical conductivity. Resistance to intense chemical activity. Electrical discharge generates UV light which then causes fluorescent powder to emit visible light. High efficiency. Long life: 3,000 – 5,000 hours, i.e. about one year of continuous use.	Automatic drawing.	Soda lime silica glass % SiO_2 72.5 Al_2O_3 2.6 CaO 5.7 MgO 2.9 Na_2O 14.6 K_2O 1.2 B_2O_3 0.3

4- Domestic and industrial shades and bulkhead lights	Resistant to high temperature. Resistant to thermal shock. Resistant to weathering. Accurate and non fading color: subject to strict BS specifications.	Mouth blowing. Hand and automatic pressing – depending on quantities required.	1. Soda lime silica glass. 2. Laminated with optical glass. 3. Borosilicate glasses andopal glasses

Table 3:Annual Operating Cost Comparison of Diversion and Disposal for Glass recycling

	Diversion	Disposal
Operational costs		
Labor	$1,560	$0
Transportation	$600	$1,800
Landfill Fees	$0	$300
Total Operational Costs	$2,160	$2,100
Total recovered Income	$180	$0
Net Annual Cost/Benefit	-$1,980	-$2,100

APPENDIX B

Cost Benefit Analysis
for
Andela Pulverizer System

Assumptions:

ITEM	VALUE ASSUMED
Revenue for accepting recyclables and/or glass (ton)	$25.00
Total glass recycled (tons/day)	20
Fraction of glass that is mixed broken glass (MBG)	0.40
Labor costs to sort glass by color (ton)	$-10.00
Transportation costs for bringing glass to beneficiator (ton)	$-7.00
Transportation cost for MBG (ton)	$-5.00
Tipping cost for disposal for MBG (ton)	$-45.00
Prices of FLINT at beneficiator (ton)	$30.00
Prices of AMBER at beneficiator (ton)	$25.00
Prices of green at beneficiator (ton)	$5.00
Price of pulverized glass at recycling facility (ton)	$5.00

Costs breakdown by type of glass					
Item	Flint	Amber	Green	MBG	Andela Glass
Tons processed/day	7.20	3.00	1.80	8.00	9.80
Labor for sorting (ton)	$-10.00	$-10.00	$-10.00	$0.00	$-1.00
Transportation costs (ton)	$-7.00	$-7.00	$-7.00	$-5.00	$0.00
Tipping at beneficiator/disposal (ton)	$30.00	$25.00	$5.00	$-45.00	$5.00
Pulverizer system operational costs (ton)					$-1.50

Option 1: Sorting glass only				
	Flint	Amber	Green	MBG/Residual
[total: 20] tons/day	7.20	3.00	1.80	8.00
Labor to sort glass	$-72.00	$-30.00	$-18.00	$0.00
Transportation costs	$-50.40	$-21.00	$-12.60	$-40.00
Income or cost at destination	$216.00	$75.00	$9.00	$-360.00
Totals	$93.60	$24.00	$-21.60	$-400.00
TOTAL COST OR INCOME/DAY:				$-304.00

Option2: Sorting Glass and Andela Pulverizer				
	Flint	Amber	Green/MBG/Residual	
[Total:20] tons/day	7.20	3.00	4.80	
Labor cost	$-72.00	$-30.00	$-9.80 (1/2person)	
Pulverizer maintenance costs	N/A	N/A	$-14.70	
Transportation costs	$-50.40	$-21.00	$0.00	
Income or cost at destination	$216.00	$75.00	$49.00	
Totals	$93.60	$24.00	$24.50	
TOTAL COST OR INCOME /DAY				$142.10
SAVINGS PER DAY WITH ANDELA GLASS PULVERIZER				$446.10

THE BOTTOM LINE	
Revenue For Accepting The Glass (/day)	$500.00
Cost Benefit For Processing Glass With Andela Pulverizer (/day)	$446.10
Lease payment for glass pulverizer system (/day)	$-100.00
TOTAL BENEFIT FOR PROCESSING PER DAY	$846.10

APPENDIX C

General Information

Table A: European glass recycling 1989

Country	Tons collected	Share of national consumption
Austria	115,000	54%
Belgium	208,000	60%
Denmark	58,000	36%
Finland	18,000	36%
France	760,000	38%
W. Germany	1,538,000	53%
Great Britain	310,000	17%
Greece	14,000	13%
Ireland	11,000	13%
Italy	670,000	42%
Netherlands	279,000	57%
Norway	11,000	24%
Portugal	34,000	14%
Spain	287,000	24%
Sweden	42,000	34%
Switzerland	164,000	56%
Turkey	47,000	27%
Total	4,566,000	38.7% average

Table B: United Kingdom recycling figures 1997

Total glass including flat recycled in 1997	511,000 tons
Total glass packaging recycled in 1997	441,000 tons
National production of glass in 1997	1.96m tons
Percentage of glass packaging recycled	22.50%
Percentage of glass recycling including flat	26.07%
European average recycled	Over 50%
Number of districts with bottle banks sites	436 (all)
Total number of bottle bank sites at end of 1997	22,074
Current number of public bottle bank sites	16,735
Current number of commercial bottle bank sites	5,339
Bottles and jars in a ton	3,000
Bottle and jars per kilo	3
Year of first bottle bank scheme	1977
Glass as a percentage of the average household dustbin	8-10%
Current ratio of bottle bank sites per head of population	1:2,500
Current European ratio of bottle bank sites per head of population	1:1,000

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