Ecodesign in Food packaging

Unit 7: Glass Containers

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After learning this unit, the student will be able to:

- To know the properties and the technological process of glass containers
- To be informed about the characteristics and possibilities of glass containers packaging
- To be informed about the recovery, recycling possibilities and about the life cycle of glass containers.

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7.1. Glass, definition, types,properties

The glass is known and used for over 4000 years. In Antiquity (Phoenicia, Syria, Egypt, Rome, etc.) technologies for obtaining various complicated and colorful glass objects have been developed. The manufacturing process of glass by the phoenicians sailors is essentially the same one used today. A mixture of purified sand is heated to a high temperature of over 1000°C with sodium and calcium carbonate together with sodium sulphate. The gases helps in mixing the melt. The addition of calcium is necessary to make the glass insoluble in water – the simple sodium glass is soluble in water and gives a very thick liquid, known as water glass (used as a preservative for egg during the second world war).

American Society for Testing Materials defined glass as "an inorganic fusion substance which has cooled in a rigid condition, without crystallizing "(ASTM, 1965).

Glass has an amorphous structure. To the cooling of the indicated mixture, the bottle has a structure similar to a liquid but the viscosity is similar to a solid and basically it behaves like a solid. The silico (60-70%) – calco (13%) – sodium (12%) glass is the basis of the manufacture of the majority containers for food packaging with the cheapest raw materials, sand, limestone and soda. These are sustainable natural materials. Glass is the packaging material most preferred by consumers which are concerned about their health and the environment. Consumers prefer the glass packaging because they keep the food taste and smell and keep their integrity. The glass is recyclable 100% and it can be reused endlessly without loss of quality or purity.

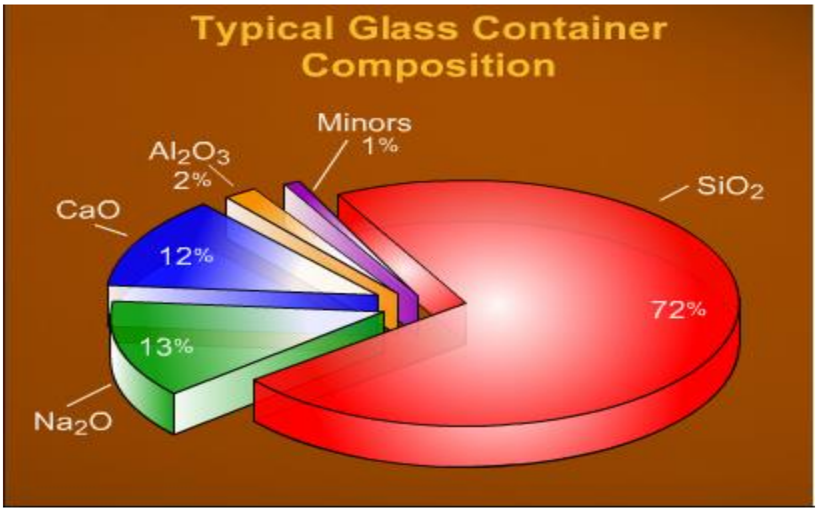


Fig. 1 The typical composition of glass for food containers. Source: Glass Packaging Institute.

The bottle is used as packaging material due to its advantages: it is insoluble in water and resistant to acids and bases; it is chemically inert in contact with food; it is impermeable to gases, liquids, vapors, aromas, microorganisms; it is cheap; transparent, it allows the view of the product; it is easy to clean and rigid.

The bottle has the following disadvantages: transparency; light can contribute to the quality changing; it is brittle, it is not resistant to shocks, vibrations, collisions; it has an important brittleness, it cracks under the action of thermal shocks if the temperature is beyond 30-35 °C and also to mechanical shocks; it has a relatively high density, 2500 kg/mc; it requires special conditions of handling, transport, storage.

Depending on the color, the glass is classified into the following types:

- colorless glass (white glass) is used for: the jars manufacture for vegetables and fruits canned; the bottles manufacture for mineral water, juices, soft drinks, alcohol, spirits; ampoules and carboys;

- semi - white glass (blue-yellow)– blue bottles for the mineral water and yellow bottles for the white wine;

- light green and dark green bottle –for the bottles manufacture for champagne, wine, beer;

- dark yellow bottle (amber)–is used for the bottles manufacture for beer, red wine;

- brown bottle - for the bottles manufacture for beer[1].

A wide range of foods is packed in glass containers. Examples: instant coffee, dry mixes, spices, baby food, dairy products, sugar, canned (jams and marmalades), spirits, syrups, processed fruits, vegetables, fish and meat products, mustard and spices, etc. In these categories of foods and drinks, the products vary from dry powders and granules to liquids (some of them are carbonated and under pressure packed) and products that are thermal sterilized.

[1] LILIANA GÎTIN AMBALAJE ŞI DESIGN ÎN INDUSTRIA ALIMENTARĂ UNIVERSITATEA

7.2 The technological process of glass containers production

7.2.1 The technological process of glass containers

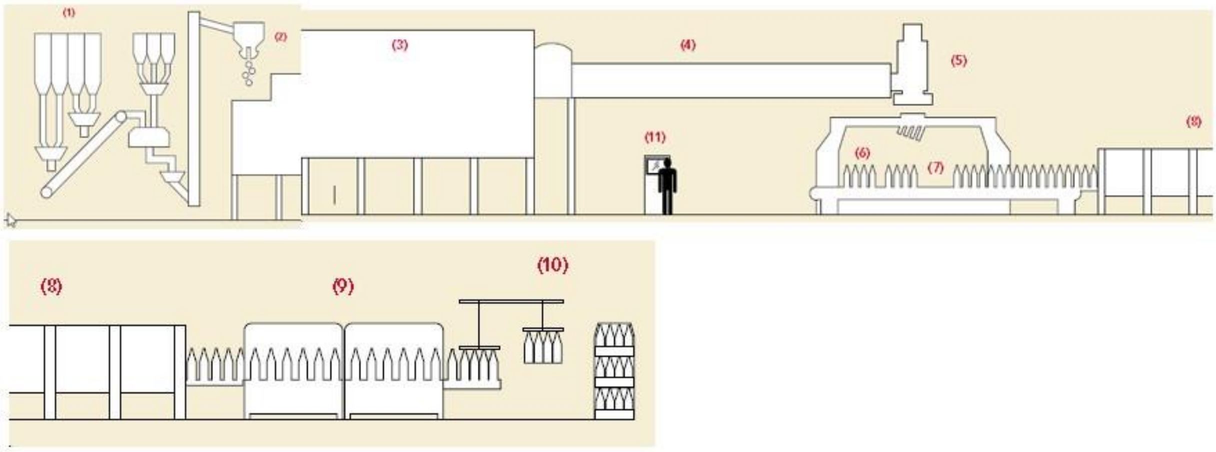


Fig.2 The technological process of glass containers, according to [*http://www.bucheremhartglass.com/node/22765*](http://www.bucheremhartglass.com/node/22765)

1 – the storage and supply installation of raw material, 2 - the batch dispenser, 3 – the melting oven, 4 - the conditioning crucible (transport and uniform heating) of the melted glass, 5 – the feeder with piston, 6 – the container formation, 7 – the storage, 8 – the annealing oven, 9 – the containers control, 10 – the containers packing on pallets, 11 – the car control

1 – the storage and supply installation of raw material which contains glass shards (recycled broken glass), sand, soda, mineral: calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$) and feldspar (a silicate, very spread ore). The shards are used in different proportions, 20-30% up to 60-90% in high performance installations. For the production of different colors iron oxide (green), sulfur (amber – color between yellow and orange), and cobalt (blue) are added, then are sorted and mixed according to the technological formula and transported by an elevator to the batch dispenser - 2 which continuously feeds the oven – 3 which can use electricity or fuel (natural gas or oil derivatives) to heat the batch at 1050-1200 °C, in other cases 1400-1600 °C. For saving energy and reducing the impact on the environment, to the ovens on fuel is used the energy of burnt gases to preheat combustion air, batch drying and other purposes. The melted glass is led through one or more crucibles 4, which are actually extensions of the oven through which the melted glass is run and which ensures the uniform heating of the melt along the way, the process being named as conditioning of the melt glass. The next step is the formation of

the glass droplet in weight, diameter and length, according to the size and format of the article intended to be poured.

For this, the conditioned bottle enters in a plunger feeder, 5, which pushes it down through a narrow tube at the base of which the glass flow is cut forming a piece of glass – drop. The next stage is the container formation, 6, which is usually a bottle (glass bottle) or jar. For bottles, the process is double blowing, and for jars process is the pressing – blowing.

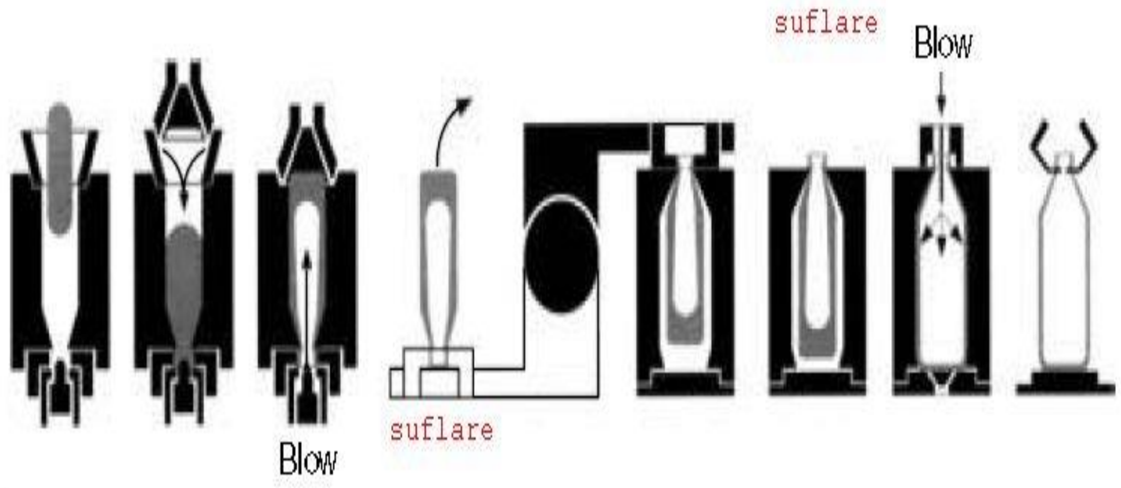


Fig. 3 The bottles formation

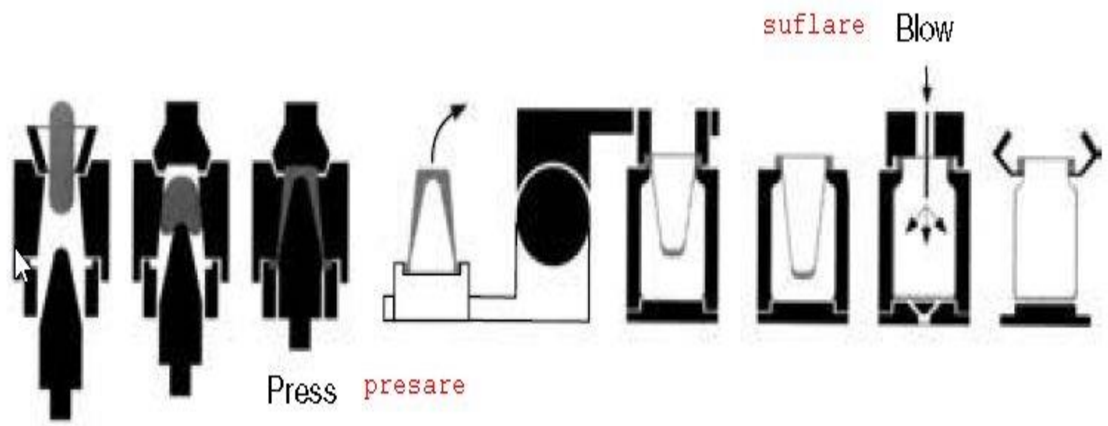


Fig. 4 The jars formation[2]

[2] RICHARD COLES, DEREK MCDOWELL, MARK J. KIRWAN FOOD PACKAGING TECHNOLOGY, Blackwell Publishing Ltd, 2003

Production lines for glass containers present many units (or sections) which form the indicated containers. There are lines with up to 12 sections. In addition to the production of a single container (known as the production of a single drop) it can work simultaneously with multiple drops, being achieved two, three or four containers. After the complete formation, the containers are removed from the plant (7). Then, an automatically pusher transfers them to a conveyor belt. The conveyor is carrying the warm containers to the annealing oven, (8) where the containers are reheated approximately to 580°C and then the containers are cooled slowly for stress relief. At the exit of the annealing oven the containers are cold and they can be inspected (9) manually or with tools. Today, the fully automated devices use physical and visual tests to check if each container has the right size, shape and thickness. Also, it checks the existence of any cracks, bubbles and foreign bodies which are known under the name of stones (are usually pieces of refractory material which have been broke away). The improper containers are rejected. Finally, the finished containers are carefully packed and they are placed on pallets or in boxes (10) ready for transport to the client's factory, where they will be filled, labeled, sealed and distributed for sale. The system (11) controls the forming machine. In the past, the glass production has been controlled mechanically, by qualified engineers who have made manual adjustments. Later, electronic controls have been developed and today the control function can be computerized.

7.2.2 Surface coatings

a) Outer coatings- Many glass containers are covered to the outside with two layers. The first layer is called " hot end" and it consists of a tin oxide that is applied after the annealing before the formation. The second is named "cold end" and it is applied after the formation and it consists of an oleic acid or polyethylene wax layer. The first layer provides the adhesion between the glass and cold end. The cold end reduces the friction between the glass containers during transport and it decreases the danger of breakage.

b) Inside coatings- They consist in the injection of sulphur or fluorine salts to reduce the glass alkalinity by replacement of sodium ions with hydrogen ions. This coating is rarely applied to the containers intended for food that have a natural resistance to becoming alkaline, it is applied to the beverages containers, e.g. liquor, and to the pharmaceutical containers where glass is replaced with boron which is more expensive.

7.3 Ecodesign of glass containers used as packaging

7.3.1 Design elements of glass containers

One of the design parameters that should be taken into account when the functionality of a glass container is important is the inclination angle. For a jar with wide hole it should be ≥22 ° and for a bottle it should be ≥16 °. These parameters indicate the lowest degree of stability the container can stand.

In fig. 5 the different forms of glass containers are presented:

Fig. 5 Glass containers

http://www.commissionoceanindien.org/archives/

In fig 6, 8, 9 are presented the main elements of the jar and cover design. http://www.ehcan.com/JarsClosure.html

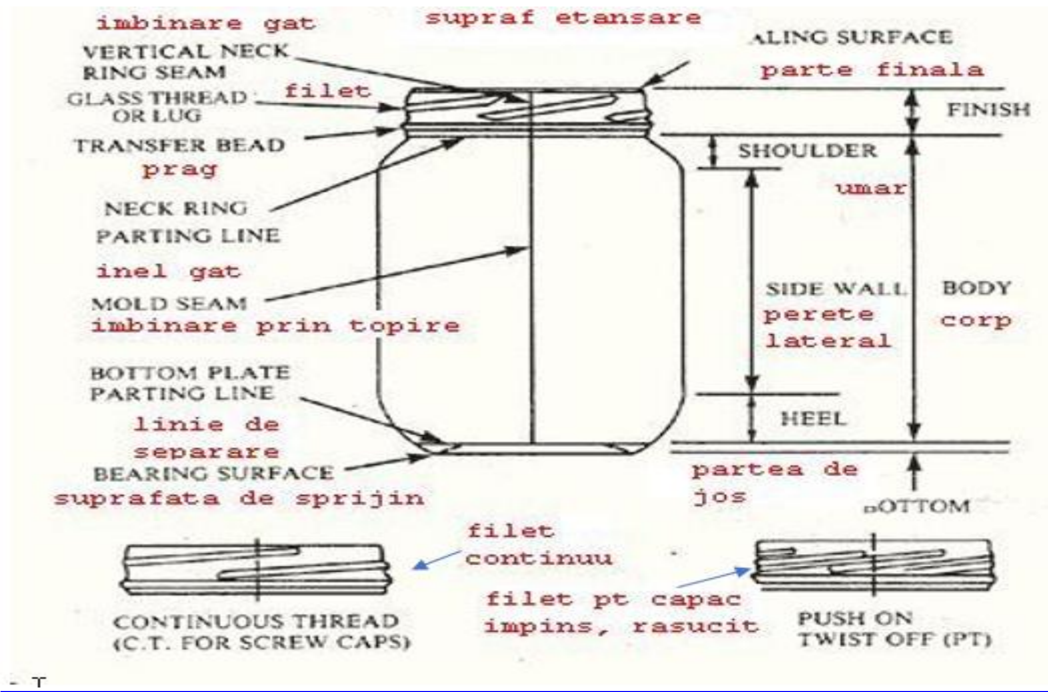
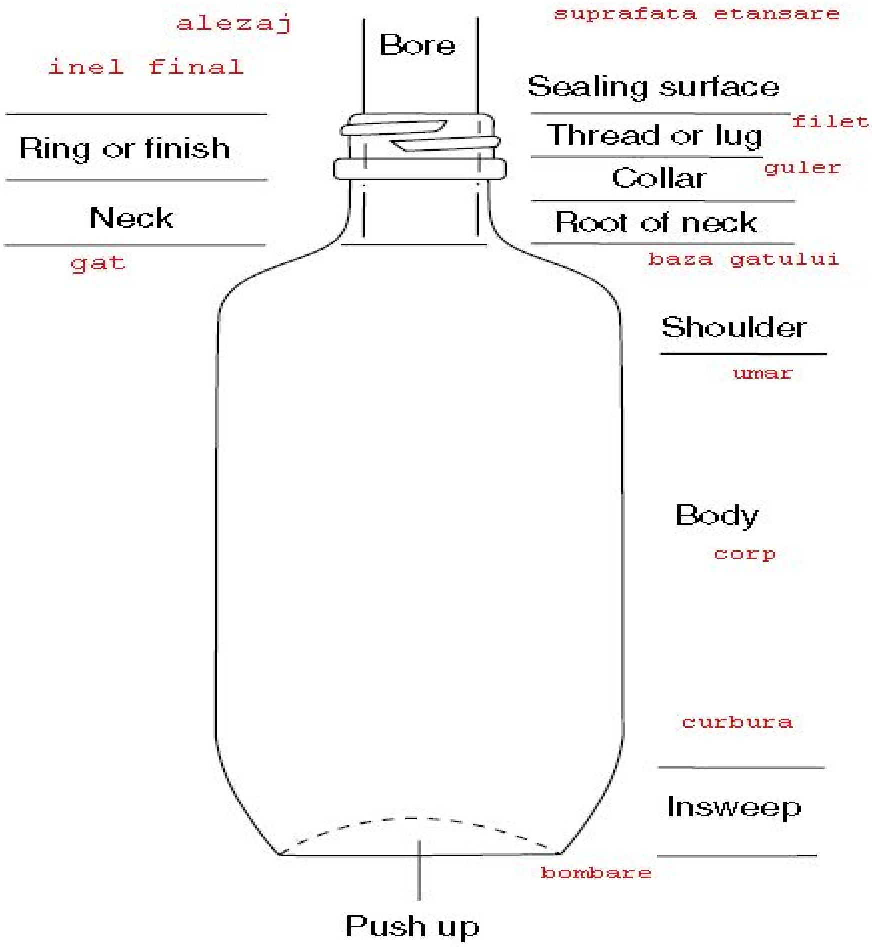


Fig 6 The components of the jar.

In fig. 7 are shown the component elements of the cylinder of glass:

Fig 7. The components of a glass bottles. After RICHARD COLES, DEREK MCDOWELL, MARK J. KIRWAN FOOD PACKAGING TECHNOLOGY, Blackwell Publishing Ltd, 2003

For sealing the means most common are: the stopper continuous-thread , the cork or substitutes, the cork stoppers or replacements, pressed crown cap or threaded crown. For the filling it is recommended that the diameter of the filler tube to be smaller with 1 mm than the bore of the bottle.



The neck and shoulders provide space for thermal expansion and they facilitate the bottle filling. On the body area the labels are applied. The bottom insweep is a traditional application which highlights the bottle quality. The base of the bottle has a flat or curve area on which the bottle in the form is placed.

7.3.2 Closures devices for jars

a) vacuum seal food closures

The closure for continuous threaded fig. 8, consists of a steel case and it can have from three to six ears, depending on the diameter. Normally, it contains a plastic gasket.

The application and the sealing - the inner space of the jar is cleaned with steam such as the other ways of closure. The closure is screwed on to the final part of the jar. It is desirable, in most cases, gasket is soaked on heat to facilitate the sealing. Both the thread and the vacuum created to fill the jar, keep pressed closure, but the most important is the vacuum.

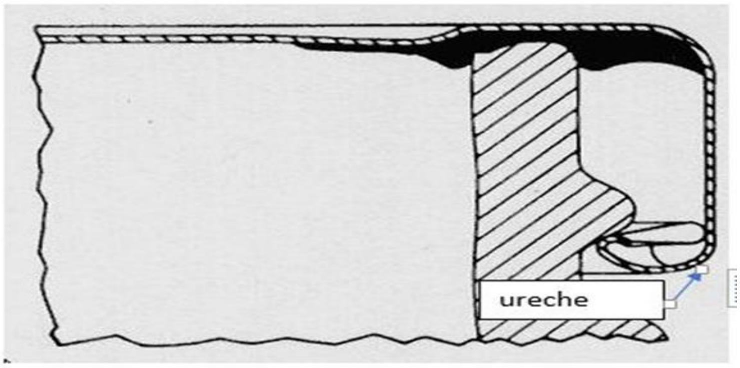


Fig. 8 The jar closure with continuous thread and Press-on Twist-off cap

PT Press-on Twist-on Cap fig. 9 consists of a steel case without ears . The gasket is made of molded plastic which covers an sealing area that extends from the upper outer edge of the closure to the closure curvature, forming the primary upper sealing and a secondary gasket on the side. The application requirements require the pressing down of the closure on glass the surface after the steam flows over the upper space. The PT closure gasket should be heated properly before application. The gasket glass fibers are deformed on the closure side and they allow the closer to be locked when it is twisted.

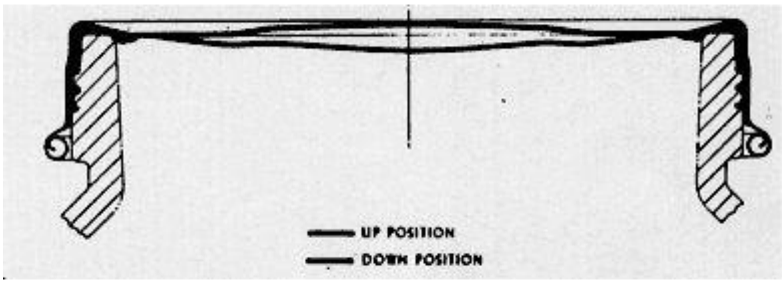


Fig. 9 PT Press-on Twist-on Head

b) Other jars caps

There are many other forms of caps, which are less common and which differ by the manner of the seal. In fig. 10 are shown a few examples.

Fig. 10 Various closing lids of the jars. . https://sha.org/bottle/closures.htm

7.3.3 Closing seal devices of the bottles

Bottle closure is performed with closing seal devices of the bottles which does not allow to occur contents leaks of the bottles, evaporations or contact with atmospheric air. These are:

Fig. 10 Example of cork applied.https://sha.org/bottle/closures.htm

- **The cork** is the most common and most traditional sealing device of the bottle. He comes from the cork tree shell which grows in SE of Europe and Africa.

- The cork elasticity means the ability to keep the normal size after compression -it was the base property of the cork, allowing it to be tightly in the hole of a bottle and create a gasket. In addition, its chemical inertia made it ideal forthe sealing of any type of bottled product - liquid or solid - without provide flavor to product. The cork, when it is kept wet by the glass content, also ensures the seal over a long period of time, which is one of the reasons that cork is still used today for bottles of wine. For other uses there there is a tendency to replace the cork with a synthetic plastic.

- One of the most common closures without cork is the large and varied group of threaded closures. They come in both versions with external thread and internal thread. Caps with internal thread are usually made of hard rubber or other plastics. Caps with external thread vary greatly and are made from more materials - usually different metals and, more recently, plastic or rubber.

Fig. 11 Example of plugs threaded to inside and outside
https://sha.org/bottle/closures.htm

- **The crown cap** - this closure consists of a simple metal lid with a corrugated side and a compresible lining (cork initially and plastic now). The standard size of the crown or the upper finishing part is 1 ", outer diameter (~ 2.5 cm). The cap is pressed into the lock position with a special device or a special pressed machine. To access the vial content, a manual, very familiar device for bottles opening is used.

Fig. 12 The bottle and the crown plug applied

https://sha.org/bottle/closures.htm

Types of pressed plugs:

a) crown capsule – the capsule of steel sheet, with the wavy edge fig 12.

b) ring crown head - the capsule of steel sheet, with overturned edge with extension that facilitates the opening, fig 13.

Fig. 13 Capsule with breaking ring

http://www.finn-korkki.com/en/caps-and-closures/

7.4 Options concerning the end of life

7.4.1 The glass containers re-use

It represents the highest scenario of end-of-life in accordance with the waste hierarchy, but the glass container is now reused only in a limited way, for the most part to the small factories of dairy products.

7.4.2 The recycling system with closed loop for glass containers

Through the use of pieces in glass production, it is in the present, the scenario most beneficial for the end-of-life of the glass container. Due to the fragile nature of the glass, the type of used collection system has a big impact on the quality of the recovered glass. For use as a raw material in the production of new glass, recovered glass must be sufficiently free of small fragments and contaminants, which is difficult to maintain in a collection system with a stream. According to Morawski (2009), only 40% of the recovered glass in the collection systems with a stream retain the required level of quality, while the other 60% are landfilled or sold for uses with lower value, eg. aggregate for roads. The same study showed that in a system with dual stream, in which the glass is separate kept from other recyclable materials, 90% of recovered glass have a high quality, while the remaining 10% is sold for uses with lower value; in systems of containers storage, 98% of recovered glass have a high quality, while the other 2% are sold for uses with lower value.

In addition, the collection systems with single stream have as result small fragments of broken glass which are embedded in paper products or they are trapped in plastic and metal containers, contaminating these materials and decreasing their value. If the glass will be used as cullet for production of new glass or fiberglass containers, it must be broken into pieces of uniform size, they are as possible, cleaned of many contaminants and the cullet must be sorted by color. The first step in this process is usually the glass containers crushing if they are not already broken. The screeners can be used to separate the small glass pieces from bigger contaminants, less fragile that can't break, such as cork.

The cullet can be sent to a automated sorting equipment, such as a magnetic separator for the removal of the steel lids and a eddy currents separator to remove the aluminum pieces. By passing the glass through an air stream the labels and other light contaminating items can remove[3].

7.4.3 The results of a LCA assessment for the glass containers

Life cycle assessment-LCA allows the analysis of different stages from the life cycle of a product:

1) the assessment of activities or independent phases (Gate-to-Gate) - evaluates a plant or operation;

2) the assessment of a partial cycle (Cradle to gate) - includes assessments carried out according to the 1st point with the addition of suppliers before that activity (raw materials, materials, processing and transport);

3) the assessment of the entire life cycle of the product (Cradle-to-grave) - from extraction to disposal;

4) the assessment of the entire life cycle of the product including its recycling (Cradle-to-cradle) - includes the entire life cycle of the product with the addition of the product recycling back to the original purpose.

To get a clear and accurate picture of the entire life cycle for glass containers, Glass Packaging Institute (GPI) has realised an LCA[4] for the glass containers production in North America of cradle-to-cradle type. LCA cradle-to-cradle of the made glass container, addresses all the inputs and outputs for the production and management of the end of life for 1 kg of container glass, which includes:

- The extraction and the processing of raw materials and the recycled glass cullet
- The transport of raw materials and cullet
- The production and the consumption of fuel and energy for melting and the formation of glass (including for other not directly related activities to the melting from plant)
- The impact of the rejected cullet treatment at melting
- The transport of the finished container to the final user.

The results of the cradle-to-cradle scenario refer to 1 kg of glass for the market containers. A reduction of the the ecological burden of enterprise to the production of glass with the increase of the glass recycling and reprocessing for the containers is found.

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[3] Elizabeth Shoch, Adam Gendell, Anne Johnson, Matt Thomas *Closing the Loop: Design for Recovery Guidelines for Glasss Packaging* by GreenBlue

[4] The Glass Packaging Institute, Cradle-to-Cradle Life Cycle Assessment of North American Container Glass, 2010, www.gpi.org

In general, with the increase of recovery and recycling the consumption of energy is reduced and the Global Warming Potential GWP is decreased. The greater benefit for GWP is generated by energy consumption decreasing and CO_2 emissions reducing with the reducing of raw materials consumption by their replacing with cullet.

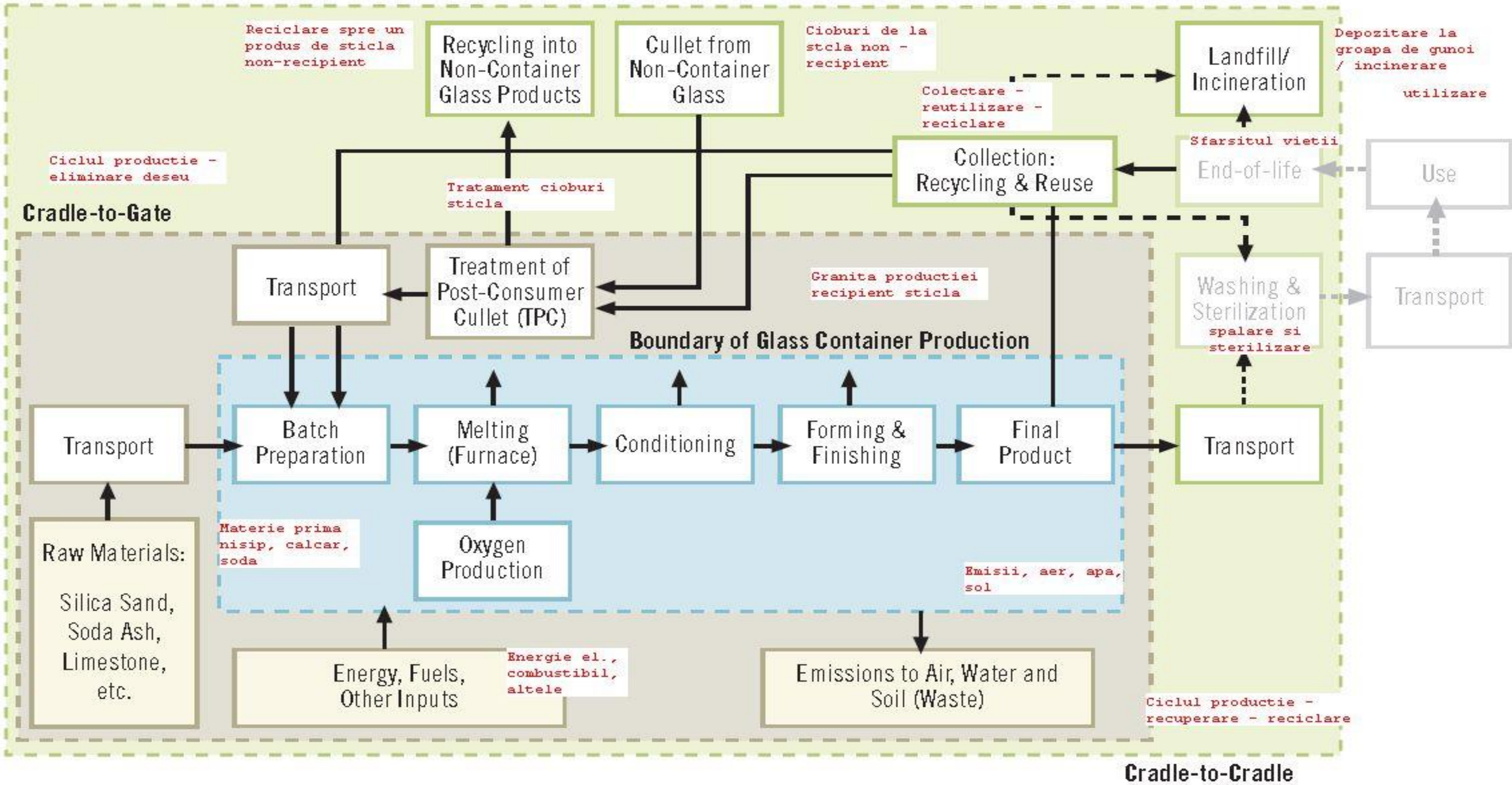
The 50% recycled cullet in the raw material scenario shows a decrease of 10%

of the GWP in the cradle - to-cradle scenario compared to the cradle - to - gate scenario which doesn't use recycled cullet.

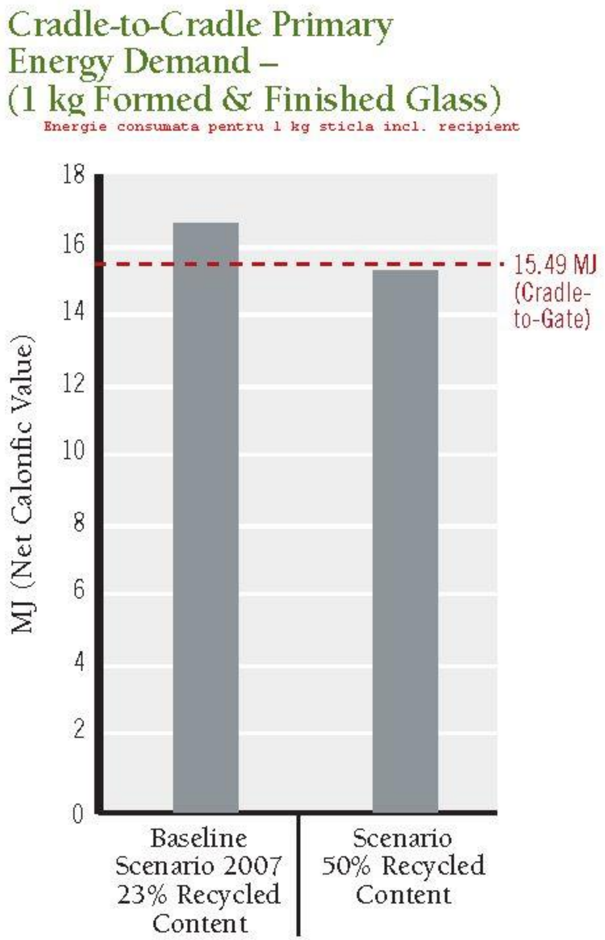
This highlights the importance of a cradle-to-cradle study when the LCA for a product should be prepared.

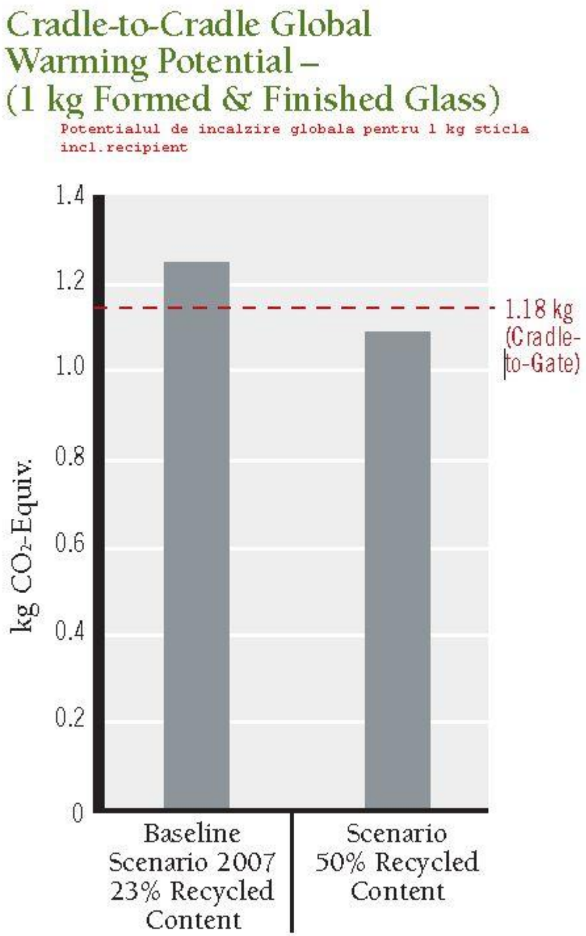
For GWP, the reference value is 1.26 kg CO_2 per 1 kg of glass containers production on the market and the reference value of the scenario with recycling is of 50% and it leads to a decrease at 1,11 kg equivalent CO_2. In other words, the recycling rate of 50% can eliminate in North America 2.2 million metric tons of CO_2 from the environment, the equivalent of the emissions eliminating of CO for about 400,000 cars every year. To an energy consumption up to a recycling rate of 50%, substantial savings do not appear but to the increase of the recycling percentage, these savings become substantial. It is emphasized that the recycling percentage to the performing plants has reached 90%.

In annex 1 the diagram of the glass containers production flow is presented for cradle-to-cradle LCA, also the LCA results regarding the energy consumption and global warming potential of the production of 1 kg glass is moulded as a container.



Flow diagram of glass containers production used in the LCA study The Glass Packaging Institute, Cradle-to-Cradle Life Cycle Assessment of North American Container Glass, 2010, www.gpi.org





The LCA study results for North America. From The Glass Packaging Institute, Cradle-to-Cradle Life Cycle Assessment of North American Container Glass, 2010, www.gpi.org