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Circular Economy in the Glass Industry

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Circular economy is a concept we cannot live separated from it in today's world. It creates and regenerate value, through transformation of waste into a valuable resource.

Glass production is pioneer in implementation of circular economy and an example that should inspire other areas. Glass waste is a non-biodegradable material. Its recycling reduces landfill space, save energy and natural resources, and reduce CO_2 emissions.

Global population growth and the resulting increase in consumption and waste production, and the growing use of glass in the food, beverage, cosmetics, pharmaceutical and automotive industries, electronics, as well as its use as an alternative to plastic containers, further promoted the relevance of glass reutilization.[1, 2]

Glass reuse was limited at the beginning to recycling. Glass recycling can use quantities of waste above 50%, in the case of the production of brown or green container glass. It can be ranked first if the amount of added cullet is used as a classification parameter. It has the disadvantage of using basically glass cullet as reusable material. Figure 1 shows reduction of energy achieved when glass cullet is melted.[3]

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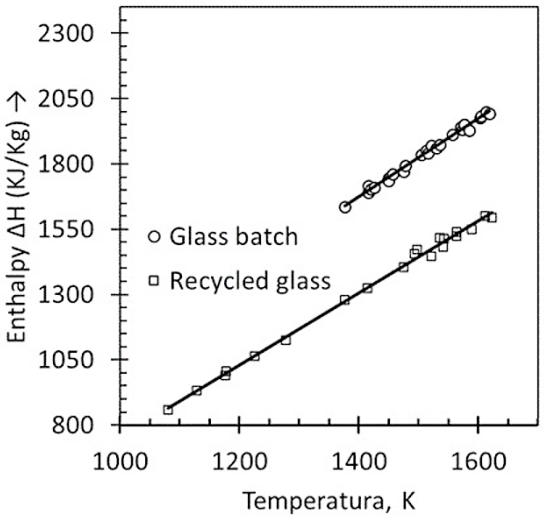

Fig.1: Theoretical energy demand for the production of glass melt from glass batch and from recycled glass in kJ/kg glass

Later, glass industry incorporated calumite and ecomelt in the batch. These are amorphous materials obtained as secondary products from the metallurgical industry. Main components present in glass batch and glass cullet of a white flat glass, calumite and ecomelt are.[3]

- **Glass batch:** 58.21% sand, 18.76% soda, 5.24% lime, 15.89% dolomite, 0.53% sodium sulfate and 1.37% nepheline syenite;
- **Glass cullet:** 71.64% SiO_2, 13.72% Na_2O, 9.36% CaO, 4.03% MgO and 0.696% Al_2O_3;
- **Calumite:** 33.75% SiO_2, 44.10% CaO, 4.70% MgO and 13.50% Al_2O_3;
- **Ecomelt:** 37.60% SiO_2, 41.50% CaO, 8.10% MgO and 9.40% Al_2O_3.

Compared to glass cullet, calumite and ecomelt require fewer energy for production of one kilogram of melt (See Table 1). This comparison should take into account the difference of chemical composition of calumite and ecomelt, when compared to glass cullet.

Table 1: Theoretical energy demand for production of glass melt from glass batch, glass cullet, calumite and ecomelt

Materials used	Temperature (K)		Energy saving
	1400	1600	
$\Delta H_{glass\ batch}$ (KJ/Kg)	1674	1975	---
$\Delta H_{glass\ culllet}$ (KJ/Kg)	1306	1582	20 – 22%
$\Delta H_{calumite}$ (KJ/Kg)	656	1047	47 – 61%
$\Delta H_{ecomelt}$ (KJ/Kg)	588	946	52 – 65%

In addition to the environmental impact and saving of energy, calumite and ecomelt are considered sustainable raw materials for the glass industry. Their use is associated with improvements of the glass melting process; quality of the glass (it promotes dissolution of silica and the occurrence of reactions taking place during glass production) and of the stability of glass color (See https://calumite.co.uk/assets/Calumite-002.pdf).

In recent times, new research results show use of waste glass in areas different from glass industry. Glass is used as a partial substitute for cement, due to its pozzolanic properties, and also as a partial substitute for sand.[4] The first experiments using glass as an inert aggregate and partial substitute for sand showed unsatisfactory results due to the occurrence of reactions with the alkali metal oxides present. This phenomenon can be mitigated by the addition of pozzolanic materials such as fly ash and blast furnace slag, which react preferentially with alkaline solutions. The combined use of glass powder and fly ash has a beneficial effect on improving the development of mechanical strength in the early ages of concrete curing.[4] Glass powder is also used in the production of ceramic materials. Its incorporation into the ceramic mass reduces the firing temperature of the ceramic material and improves energy efficiency. Glass powder melts at low temperatures and acts as a ceramic flux that contributes to the sintering of the material, its densification, the reduction of porosity and water absorption, apparently caused by the fusion of the glass powder. It also improves compressive and flexural strength, as well as resistance to acid attack and the consequent improvement in the durability of the material.[5] The study carried out by Tripathi and Chauhan 5 shows a maximum increase in compressive strength in samples with 20% glass powder in their composition.[5] Optimum amount of glass cullet may vary depending on properties of clay and optimization of cullet content, before its use with different clays, is necessary.

The global amount of glass recycling rates practiced is on average of 20-25% of the total amount of waste glass produced, a rate that shows the great effort that still needs to be carried out to increase rate of reutilization of waste glass. Waste glass reutilization show us the importance of collaboration among different stakeholders. Production and use of waste glass with the specifications required for the different applications requires a strong collaboration among actors involved in design and implementation of policies, communities (to develop awareness and commitment of the citizens with circular economy practices) and industry and R&D institutions.

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