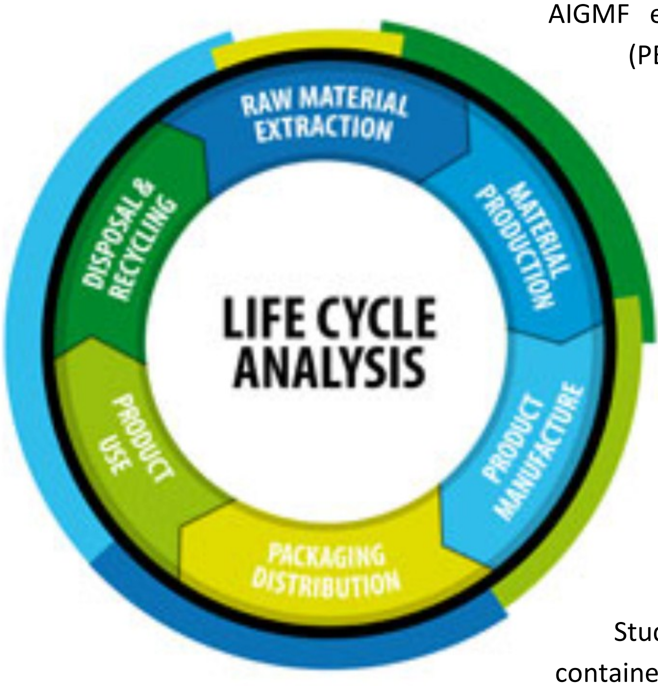
Life Cycle Assessment of "Container Glass and Comparison with Alternate Packaging Mediums (PET, Beverage Carton, Aluminum Can and Pouch)"

AIGMF

The All India Glass Manufacturers' Federation (AIGMF) founded in 1944 is the sole representative body of all segments of the Indian glass industry consisting of large, medium and small-scale manufacturers. The federation is made up of five regional associations viz., Western India Glass Manufacturers' Association-Mumbai, Eastern India Glass Manufacturers' Association-Kolkata, U.P. Glass Manufacturers' Syndicate-Firozabad, Northern India Glass Manufacturers' Association-Bahadurgarh (Haryana) and South India Glass Manufacturers' Association-Chennai. The federation consists of a total of 63 member companies engaged in the manufacture of glass and glass articles.

LCA Study



AIGMF engaged PE Sustainability Solutions Pvt Ltd (PESSPL), a 100% Indian subsidiary of PE International AG, Germany, an independent consulting company with extensive experience in conducting Life Cycle Assessment (LCA) studies and facilitating critical review processes according to ISO 14040/44. PESSPL has been entrusted to conduct this LCA study for AIGMF and also carry out the comparison with various alternate packaging materials such as PET, beverage carton, aluminium can and pouch. In the past PE International already conducted Life Cycle Assessment Study of the environmental performance of container glass production for Glass Packaging Institute (GPI) and European Container Glass Federation (FEVE) representing member companies in North America and Europe respectively.

Objective

The objective of this project is to evaluate the environmental profile of glass, determine improvement opportunities, comparison with alternative packaging materials such as PET, beverage carton, aluminium can and pouch and external communication of product environmental attributes for enhancing the green brand of glass product. This study provides the foundation for meaningful use of LCA results and will also help member companies of AIGMF to project the green image of the product amongst consumers and other stakeholders.

Goal

The goal of the study includes:

- Understanding the environmental impact of container glass – focusing on cradle-to-cradle assessment (including raw material extraction to manufacturing and end-of-life recycling).
- To identify and investigate potential improvement opportunities for container glass packaging.
- To identify and quantify the impacts of alternative packaging solutions such as PET, beverage carton, aluminium can and pouch.

The life cycle assessment is an original ISO 14040/44[1,2] compliant study. Consistent methodology and modelling has been used for this study which is also specific to India.

Critical review process

The review was performed according to ISO 14040 and ISO 14044 in their strictest sense as the data provided by the study are intended to be used for comparative assertions intended to be disclosed to the public. In order to allow credible communication based on the results of this study, a third party critical review panel comprising three independent experts:

- Prof. Dr. Matthias Finkbeiner, Technische Universerität Berlin - Department of Environmental Technology - Chair of Sustainable Engineering (Panel Chair)
- Mr. Matthias Fischer, Head of Department - Life Cycle Engineering, Fraunhofer IBP and University of Stuttgart, LBP and
- Mr. VS Mathur, General Manager, Quality and Environmental, Crop Nutrition and Agri Business, Tata Chemicals Limited, Babrala, India,

Life cycle stages

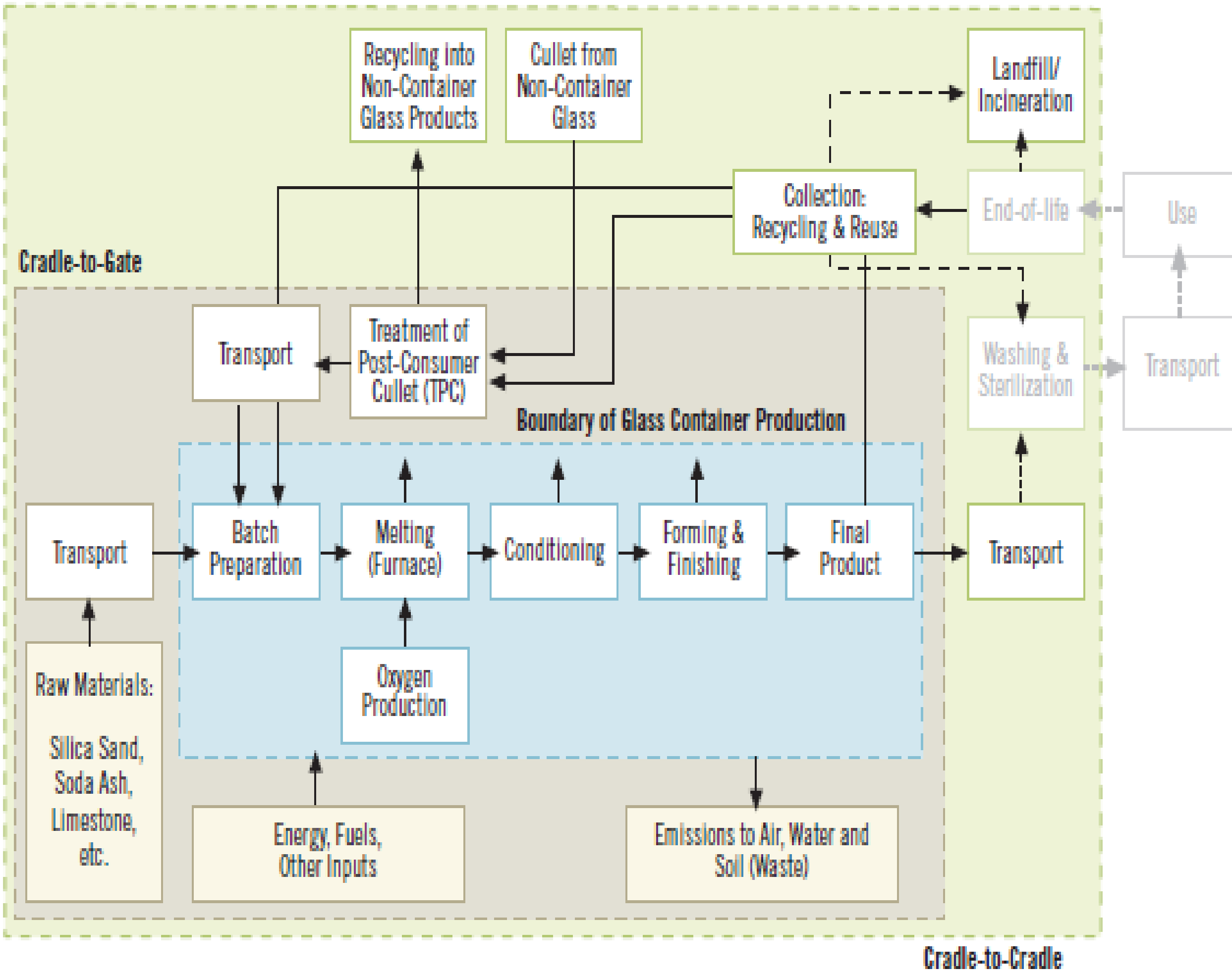
The life cycle stages of product systems that were studied included:

- Cradle-to-gate production of raw and relevant ancillary materials needed for the manufacture of container glass and alternative packaging,
- Transports of relevance over the life cycle of the glass containers and alternate packaging under study,
- Manufacture of container glass and alternative packaging,
- End-of-life of glass and alternative packaging containers covering recycling (open and close loop), reuse and disposal.

[1] ISO 14040: Environmental management – Life cycle assessment – Principles and framework (ISO 14040:2006); German and English version EN ISO 14040:2006

[2] ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines (ISO 14044:2006); German and English version EN ISO 14044:2006

Life cycle flow diagram



Source : Environment Overview Complete Life Cycle Assessment of North American Container Glass http://www.gpi.org/downloads/lca/N-American_Glass_Container_LCA.pdf

Functional Units

The following different types of glass container and alternate packaging solutions with different volumes and uses which are commercialised in India are considered in this study:

Table 1: Different Packaging Sizes and Uses of Glass Bottle

Bottle type	Glass Bottle							
Packaging Size (ml)	20	60	120	180	200	330	500	750
Packaging Use	Pharmaceutical syrup	Pharmaceutical syrup	Pharmaceutical syrup	Liquor	Juice	Beer	Ketchup	Liquor

Table 2: Different Packaging Sizes and Uses of PET Bottle

Bottle type	PET Bottle					
Packaging Size (ml)	20	60	120	180	500	750
Packaging Use	Pharmaceutical syrup	Pharmaceutical syrup	Pharmaceutical syrup	Liquor	Ketchup	Liquor

Table 3: Different Packaging Sizes and Uses of Beverage Carton

Bottle type	Beverage Carton		
Packaging Size (ml)	180	200	330
Packaging Use	Liquor	Juice	Beer

Table 4: Different Packaging Sizes and Uses of Aluminum Can

Bottle type	Aluminum Can		
Packaging Size (ml)	250	330	330
Packaging Use	Juice	Beer	Aerated Drink

Table 5: Different Packaging Sizes and Uses of Pouch

Bottle type	Pouch
Packaging Size (ml)	180
Packaging Use	Liquor

The functional unit for the base case was defined as packaging 180 ml of liquor in glass, PET, beverage carton and pouch.

System Boundary

The study includes upstream processing and production of materials and energies that make up the production of the stated functional unit, transport of materials to production sites, production of packaging solutions, transport to warehouses and customers, and end-of-life disposal. The filling process is almost identical for all the packaging solutions in a particular functional unit (packaging size) and is excluded from this study since it is independent from the finished container. The transportation emissions of filled product will differ while they are transported to warehouse or consumer because of difference in the weights of various packaging solutions and therefore it is included in this study.

Details of System Boundary Included in the Study

Life Cycle stages	Life Cycle sub-stages	Definitions
Primary packaging	Primary packaging raw materials production	Extraction, production of the raw materials to the primary packaging producer
	Packaging Formation (converting)	Energy, water and raw materials used in the process of formation of the primary packaging production and combustion during converting
	Closures raw materials production	Extraction, production of the raw materials to the closure producer
	Closures formation	Energy, water and raw materials used in the process of formation of closures production and combustion
	Label formation	Extraction and production of the raw materials of the label
	Printing ink	Extraction and production of the raw materials of the printing ink
Upstream Transport	–	Transport of the raw materials for primary and secondary packaging, closure and label.
Downstream Transport	–	Transport of the primary packaging, closure and label to the filling company.
		Transport of primary packaging from user to End of life after consumer use
		Transport of secondary packaging from retailer to End of life
		Transport of primary packaging after use from user to washing & sterilisation
		Transport of primary packaging after use from washing & sterilisation to filling station
		Transport of primary packaging after use to recycling unit
		Transport of recycled material to primary packaging manufacturing site
		Extraction and production of the raw materials of the secondary packaging
Secondary packaging production	–	Considered
Filling	–	Primary packaging, closures, labels, secondary packaging
End of life	Landfill	Primary packaging and recycling treatment plant
	Recycle	Primary packaging
	Reuse	Primary packaging (only for glass containers)
	Open burning	Primary packaging

Data Collection

In the study, site-specific data representative of current technology used in India (72% of production volume) of reference year 2010-11 were collected and analyzed for container glass. The total production volume of container glass in India was 7596 tons per day. Site visits was done for 24 sites of various member companies of AIGMF like Hindustan National Glass and industries Limited, AGI Glasspac Limited, Piramal Glass Limited, Om Glass Works Pvt. Limited, Pankaj Glass Works Pvt. Limited, Farukhi Glass Industries, Durgesh Glass Works Pvt. limited.

For alternate packaging, Indian specific datasets were adapted from European/US databases available in GaBi. Care has been taken while adopting the European model for PET, beverage carton, pouch and aluminium can regarding use of Indian electricity grid mix. The Indianized versions of the RER/DE/US datasets are prepared and boundaries are set to Indian conditions (throughout the whole value chain) for Indian electricity grid mix, Indian thermal energy and steam, Indian steam cracker and Indian refinery. The technology in any of the RER/DE/US model was chosen as close to the Indian technology as possible. The geographical coverage of this study for container glass and alternate packaging produced and consumed in India.

Regarding the primary packaging, data collection has been carried out through information provided by member companies of AIGMF involved in the study for the glass container. For other systems viz. PET, beverage carton, pouch and Al can, data has been collected from experts as far as possible and otherwise from secondary sources such as bibliography, inventories data and literature. Primary data were collected on container glass production for the year 2010-11 i.e. 1st April 2010 to 31st March 2011. These data were based on annual average data for the year 2010-11. The representative upstream data (mainly raw materials, energies, fuels, and ancillary materials) were obtained from the GaBi 5 database 2011 and are representative of the years 2008-2011, based on data availability. For alternative packing, the weight of the primary and secondary packaging was measured and European datasets for manufacturing process were used and improvised for India with India specific upstream processed from GaBi 5 database 2011. Overall, the quality of the data used in this study is considered by the authors to be high for glass and adequate for the alternative packaging systems. They are representative of the described systems of this study.

The container glass packaging solution undergoes multiple reuses. Alternate packaging solutions (PET, beverage carton, aluminium can and pouch) undergo single use.

The recycling of post-consumer container glass back into container glass describes a closed loop recycling system. Closed loop allocation applies to product systems, where it is assumed that recycled material (100%) replaces virgin material (100%).

For packaging size of 180 ml, it is on an average 30% of the total container glass packaging production in India and for other packaging sizes; it is 25% of the total container glass packaging production.

For PET, in India, the recycled product is not always used for PET bottle production. Most of the times, it is used to produce downgraded product like stuffing in toys and other lifestyle products like pillows, quilts, furniture, non-woven carpets and fabrics, medical and packaging textile, geo textile, mats etc.[3]. However, for the sake of conservativeness, we have used the recycled PET for the product of PET bottle in this study.

Consumer Concerns

There are areas that an LCA is not designed to study where glass excels for both the consumer and the environment. Recent surveys continue to show that most consumers say glass maintains the flavor and shelf life of foods and beverages longer than any other commercial container and is least likely to leach toxins into the packaged products.

- Shelf life

  The material choice for the container has an effect on the average shelf life of a food product. This may be considered when comparing different materials as it has a direct influence on the amount of product which has to be thrown away. The amount of product thrown away has a direct influence on the overall environmental performance of the packaging design in the overall context.

- Diffusion of molecules

  As different packaging materials have different levels of diffusion through the packaging (in, out as well as through) this has to be considered when assessing different packaging solutions. Diffusion of molecules is not a traditional LCA measure but as it may result in effects on the quality of the product packaged or in health effects to the consumer, these effects should be discussed when assessing different material options for packaging design.

Software

The LCA model was created using the GaBi 5 Software system for life cycle engineering, developed by PE International AG. The GaBi database provides the life cycle inventory data for several of the raw and process materials obtained from the upstream system.

[3]Corporate Presentation of Ganesh Polytex Ltd, March 2011.www.ganeshpolytex.in

Recycling

End of Life Routes of Different Materials in India and Recycling Quotas

		Recycling rate	Landfill rate	Open burning	Reuse	References
Glass	India	32.02%	37.98%	0 %	30%	Primary data collected from container glass manufacturing companies. 30% glass being reused provided by expert.
Plastics (PET bottles)	India	42%	38%	20%	0%	Report of the committee to evolve roadmap for waste management in India, MoEF, 2010[4]
Paper and cardboard	India	80%	20%	0%	0%	Country analysis paper on waste paper recycling and reuse, Third meeting of Regional 3 R forum in Asia, Dr ManjuRaina, MoEF, Oct 2011[5,6]
Aluminium	India	20%	80%	0%	0%	Recycling of aluminium, (Paper presented at Alucast 2005, organised by ARKEY Conference Service Cell, at Pune by Sunil Atrawalkar[7]
Liquid carton board	India	0.00%	80%	20%	0%	Expert Judgement
Pouch	India	0.00%	80%	20%	0%	Expert Judgement

Sensitivity Analysis

For 180 ml packaging size of all packaging systems, three sensitivity analyses have been performed in order to assess the influence of different parameters.

- Transport distances
  A sensitivity analysis is conducted for the transportation of primary packaging to the filling station for distances of 500km and 700 km.

- Weight of the packaging medium
  A sensitivity analysis is conducted for a variation in weight of the primary packaging ranging from -20%, -10%, +10% and +20%.

- EoL share of recycling

A sensitivity analysis is conducted for variation in the recycling rates of the primary packaging for 50% and 75%. The materials, which are not recycled, are considered to be land filled.

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[4]http://en.wikipedia.org/wiki/Plastics_materials_in_India

[5]Discussion paper on collection and recycling of waste paper in India http://dipp.nic.in/english/Discuss_paper/DiscussionPaper_Recycling_WastePaper_21October2011.pdf

[6]Country analysis paper on waste paper recycling and reuse, Third meeting of Regional 3 R forum in Asia, DrmanjuRaina, MoEF, Oct 2011

[7]Recycling of aluminum, (Paper presented at Alucast 2005, Organised by ARKEY Conference Service Cell, at Pune by Sunil Atrawalkarhttp://www.metalworld.co.in/feature20206.pdf

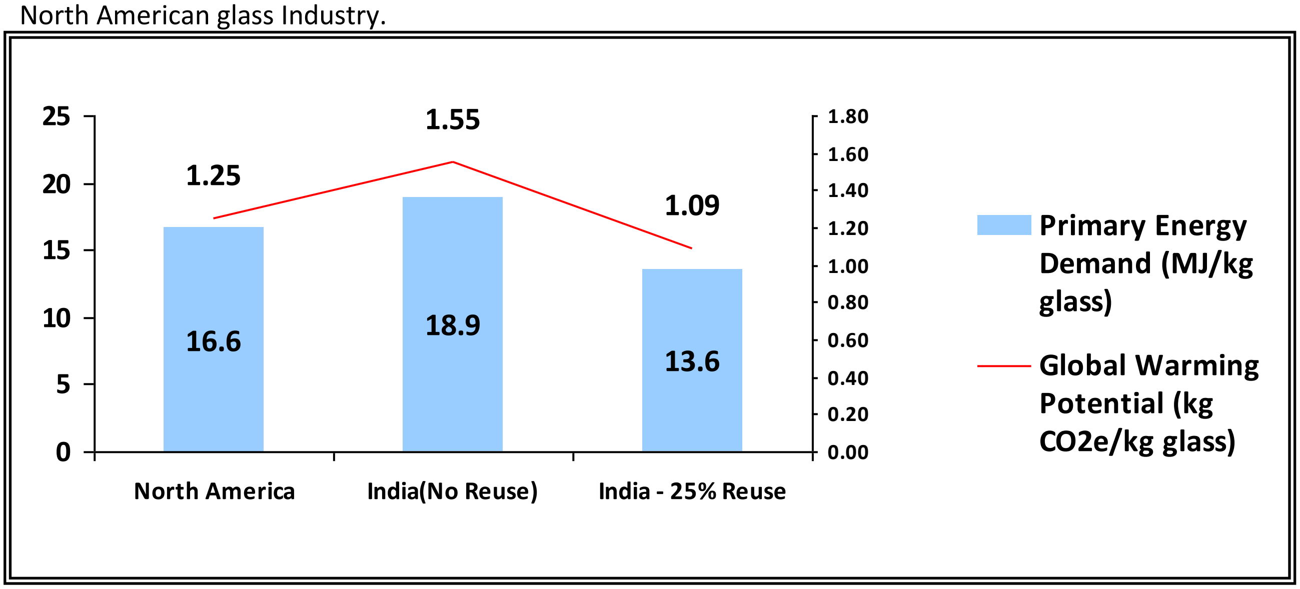
Key Results

CML 2001 (Nov 2010) method has been selected for evaluation of environmental impacts developed by Institute of Environmental Sciences, Leiden University, NL. These indicators are scientifically and technically valid.

The cradle to cradle environmental impacts for I kg of formed and finished glass is shown below in the table:

CML2001 - Nov. 2010	**Cradle to cradle LCA of 1 kg Glass**	**Cradle to cradle LCA of 1 kg Glass (GPI study)**
Acidification Potential (AP) [kg SO2-Equiv.]	8,3E-03	
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	6,0E-04	
Global Warming Potential (GWP 100 years) [kg CO2-Equiv.]	1.09	1.25
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]	0.19	
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	3,2E-04	
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB-Equiv.]	2,6E-03	
Primary energy demand from renewable and non-renewable resources (net cal. value)	13.60	16.6

The above mentioned study depicts that Indian container glass industry is performing at par with the North American glass Industry.



The cradle to cradle environmental impacts for 180 ml container glass is shown below in the table:

CML2001 - Nov. 2010	**Cradle to cradle Glass 180 ml liquor**
Acidification Potential (AP) [kg SO_2-Equiv.]	**1.2E-03**
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	**9.4E-05**
Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]	**1.6E-01**
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]	**3.4E-02**
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	**4.7E-05**
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB-Equiv.]	**4.2E-04**
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	**2.3E+00**

Comparison of glass with alternative packaging system

Table 6: Comparison of 180 ml Glass with Alternative Packaging Systems

	Glass Ref	Glass (-20% W)	Glass (75% R)	PET Ref	PET (-20% W)	PET (-75% R)	BC Ref	BC (-20% W)	Pouch Ref	Pouch (-20% W)
Acidification Potential (AP) [kg SO_2-Equiv.]	100	82	66	60	49	58	18	16	40	33
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	100	83	67	69	58	66	36	32	40	33
Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]	100	82	61	57	47	52	12	10	37	30
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]	100	85	85	123	104	123	35	28	87	70
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	100	82	57	136	111	110	39	33	85	68
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB-Equiv.]	100	83	65	246	201	177	24	21	38	31
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	100	84	69	74	63	64	44	38	50	41

90% of the waste in India goes to open landfill[8]. Recently landfill facilities have been started in some of the cities. Some of the cities have also started composting facility. Incineration with energy recovery has also been promoted in the country based on the availability and collection pattern. Apart from impact categories addressed in this study, some of the other key environmental impacts needs to be addressed such as aesthetics damage due to improper dumping on open lands, drainages, streets etc. Excerpts from Ministry of Environment and Forest of India and its concern towards the solid waste management

[8]Kumar, Sunil (2010): Effective Waste Management in India. INTECH CROATIA

practices for PET and Pouch needs special attention[9].Moreover, there are a large number of unorganized PET recycling companies (SMEs) working in India producing heavy emissions due to absence of proper pollution control equipment[10]. This will result in serious impact to human beings, which however have not been considered in this study while doing the comparison.

This study vividly reflects that improvement in recycling coupled with reduction of weight of glass containers would certainly lead to significant reduction in environmental impacts which will place it in a better position in comparison to alternative packaging systems despite higher weight of the glass for the same functional unit as compared to alternative packaging systems.

Improvement in the performance indicator due to weight reduction and improved recycling

CML2001 - Nov. 2010	Weight reduction (-20%)	Recycling (75%)	Weight reduction (-20%) & Recycling (75%)
Acidification Potential (AP) [kg SO_2-Equiv.]	**18%**	**40%**	**45%**
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	**17%**	**37%**	**44%**
Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]	**18%**	**39%**	**50%**
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]	**15%**	**15%**	**27%**
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB-Equiv.]	**17%**	**35%**	**52%**
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	**18%**	**43%**	**45%**
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	**16%**	**31%**	**41%**

Recommendations

Glass

- This assessment reflects the existing technical situation for the year 2010-11 representing 72% of the Indian production volume representing both large and small manufactures. Conditions of furnaces, due to the increasing use of abatement systems, efficiencies, rebuilds, and cleaner technologies, etc. will change over time affecting the energy and material inputs and subsequent emissions of container glass manufacturing.
- Glass industry should look for ways to strengthen glass through new surface treatment and better design without sacrificing improvement in material reduction. New technologies such as Narrow Neck Press and Blow (NNPB) forming process can help in such light-weighting efforts.

[9]Report of the Committee to Evolve Road Map on Management of Wastes in India" March 2010 by Ministry of Environment and Forest, Government of India
[10]Solid waste management in India, Ranjith Kharvel Annepu, Master Thesis, Jan 2012, Columbia University

Reduction in weight of glass will reduce material consumption and melting energy needed during the production stage. It will also reduce fuel consumption during transportation stage and increase in strength of glass increase number of reuse. This will lead of improvement of overall LCI profile of glass.

- Increase in cullet recycling rate will reduce direct material consumption and melting energy hence the overall LCI profile of glass. Better waste management for improvement of collection and segregation of glass and increase in number of cullet treatment plants (CTP) across the country will help in this.
- To improve the overall waste management system it is important to involve all the stakeholders and create awareness. Partnership with various NGO to conduct training and create awareness for the entire stakeholder should be done.
- Change of fuel from furnace oil to natural gas will significantly reduce the environmental impact and LCI profile of glass.
- Use of renewable energy like solar energy or biomass for production of electricity should be considered at bigger installations
- Reuse of secondary packaging should be increased

<u>PET and Pouch</u>

- Open dumping of PET and Pouch should be strictly prohibited.
- New environmental laws should be enacted for proper waste management of PET and pouch to reduce littering and unorganised dumping which sometimes also leads to cattle intake. Milk consumption from such cattle is dangerous to human health.
- Safer technologies for PET recycling should be promoted, in the absence of which leads to environmental degradation.
- PET and other plastics like HDPE, LDPE and Polycarbonate having bisphenol , a leach into food and beverages even at room temperatures especially when aerated and other drinks are stored in them. Hence proper care should be taken from manufacturers not to use PET in food and beverages packaging.
- If recycled plastics (thermoplastics) are used even in small quantities in the manufacture of food and beverages packaging, they cause major harm to human health as the contaminated recyclate can leach toxic hydrocarbons such as pesticides, fertilizers, lube oils, paints and heavy metals into the edible contents packed in them. Hence proper care should be taken from manufacturers not to use recycled PET in food and beverages packaging.

<u>Beverage Carton</u>

Since methane is generated during the decomposition of paper and LPB, a proper waste management should be to promote recycling and avoid landfill.