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LCA approach to the automotive glass recycling*

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Abstract—The interest of car producers in recycling of materials at the end of the car life is growing: LCA is the environmental impact analysis tool able to give useful information about the life cycle of these materials from an energy and ecological point of view. Car glass production and glass recycling from a car at the end of its life is here analyzed using the LCA methodology: in particular the energy consumption and all kinds of emission evaluation can help to understand the difference between glass from virgin and recycled material. A critical point of the analysis involving recycled materials is the energy content of the secondary materials: this case study of LCA application in the automotive industry offers a good example to evaluate the importance of this critical point and to give rise to discussion about the energy content of scrap.
Keywords: life cycle analysis; glass; recycling.

1 Introduction

The reuse ore recycling of materials and parts from cats at the end of their useful life is one of the main issue in the automotive industry environmental policies. The increasingly prominent disposal problem, the necessity to achieve the maximum energy saving and to turn down the impact on the global environment, are some of the present problems that the industry in general, and the automotive one in particular, is asked to solve. At the same time these problems could represent a new challenge to get up the economy towards a profit maximization pursuit. To plant the industrial strategies in this perspective is not just a duty for a common sustainable development but also an investment with boons especially in the green marketing activity.

2 Project description

The life cycle analysis of automotive glass production is one of the case studies that Fiat Research Centre in cooperation with Politecnico di Torino and Danish Technical University is performing in order to address Fiat choices to a real-eco-efficiency objective; moreover it is important to remember that even though the EC Eco-management and Audit Regulation still does not oblige

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business enterprise to write an environmental report of their own activities, it offers the opportunity to participate voluntarily into a system to improve the ecological performance of the production activities and to achieve a statement of participation. Following both perspectives, to turn its environmental policy towards eco-sustainable production and to be proactive in the environmental-related legislation evolution, Fiat launched in 1992 the F. A. RE. (Fiat Auto Recycling) project for automobile recycling, which provides in particular the recycling of car glasses in the glass container production.

Life cycle analysis of automotive glass production and glass recycling in the production of glass containers is the operative tool used to evaluate the energetic and ecological convenience of the recycling operations.

The main hydrothesis of thc analysis is to container to feed the glass containers production only with the F. A. RE. system glass scrap.

3 Life cycle inventory analysis

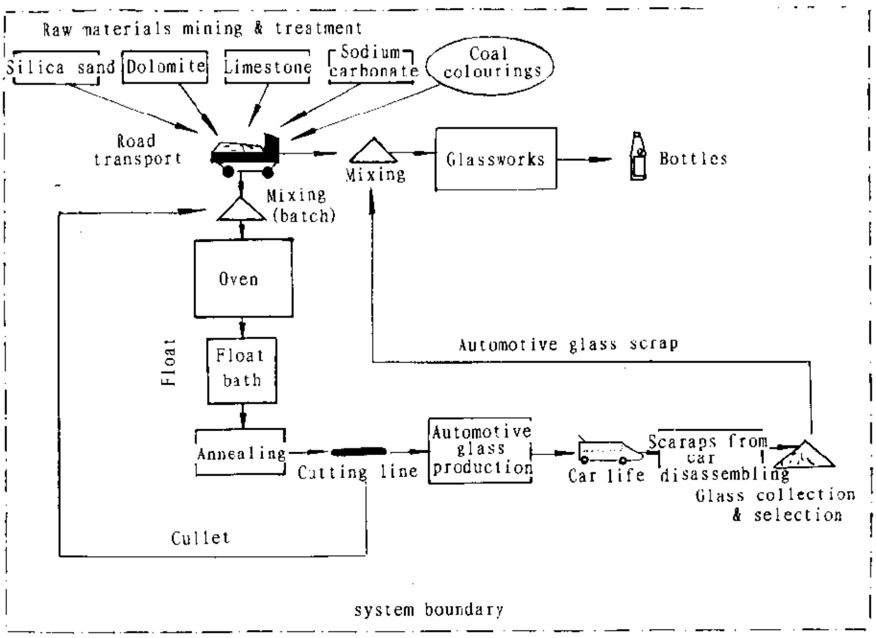

Fig. 1 Flow chart of the operations considered in the life cycle analysis

In Italy there are only three float glass produccrs enterprises: S. I. V (44% of the Italian market, Italian), P. P. G. (30%, American) and Saint-Gobain(26%, French). They all produce automotive glasses for Fiat cars: the main process' data were collected directly in the production factories, completed and adapted for the life-cycle inventory model used for calculations, the Boustead Model 2 (Boustead consulting Ltd., U. K.); this model was also an important source of secondary data and information on the energy mixes of the considered countries involved in the life cycle.

Glass is mainly a product of the mineral industry: raw material supply for float glass production is presented in Table 1; the percentage composition adopted for the case-study is an average between the considered plants. The cullet used in the float glass production comes only from broken float sheets and displaces the material mix according with quite complex chemical laws.

The raw materials supply system, except some secondary components, is the same for float glass and bottles production. With an 18 t articulated truck silica sand transportation distance is 200 km, limestone and dolomite 150 km, soda solvay and sodium sulfate 400 km; float glass cullet comes from the same considered float plants.

Inside the factory, the raw material mix enters in the float line and there is transformed in float glass; the average efficiency considered for a float oven is 82%. The resulting float sheet is then cut in the cutting line (Fig. 1) and forwarded to the transformation line to produce car glasses. Table 2 presents the input-output table used to describe the windshield production line involved in the life cycle inventory calculations.

Table 1 Virgin float glass material mix, unit (direct) energy and gross energy requirement; the gross energy value does not include the transport energy consumption

Material mix	%	Direct energy, MJ/kg	Gross energy, MJ/kg
Silica sand	61.1	0.19	0.43
Soda solvay	18.2	13.18	16.05
sodium sulfate	1.4	11.05	20.54
Dolomite	14.8	0.06	0.36
Limestone	4.4	0.04	0.13
Coke	0.1	25.42	29.95

Table 2 Materials, energy and emissions to produce 1 kg of windshield glass

Input	Quantity unit/kg windshield	Output	Quantity unit/kg windshield, mg
Float glass	1.13kg	SO_x	7
Electricity	1.05kWh	COD	95
Natural gas	0.18Nm^3	BOD	95
Lube oil	0.002kg	Dust	15
Water	221	CO_2	355200
Ink	0.3g		
Pallet	0.25kg		
PVB	0.08kg		
Grease	0.32g		

4 The F. A. RE. system

At present the F. A. RE. system includes 57 dismounting centers that in 1994 supplied 904 t of glass scrap. The scrap is crushed and selected (by air flow, by hand and finally by magnetic separation) to eliminate all the impurities and sent to the glass container producers.

Considering the present dismounting operators' capacity and the present number of 1.45 million of cars that become scrap in Italy per year, an hydrothesis of the F. A. RE. system evolution could be represented in Table 3.

Table 3 Hydrothetical evolution of the F. A. RE. system

Year	Number of cars	Cullet return, kg cullet/car	Cullet quantity, t/a
1995	100000	20	2000
1996	200000	21	4200
1997	400000	22	8800
1998	800000	23	18400
1999	1600000	25	40000

The annual glass scrap recovery in Italy is, at present, about 1 million tons: considering the annual half-white glass production (200000t), the market share of F. A. RE. glass could represent the 25% of the supply(hyp. 1999, scraps 40%).

This figure justify the importance of an energy performance evaluation of the F. A. RE. system and the interest of FIAT to perform an LCA of glass products for its cars.

5 Glass containers production

As explained before, the glass scarps coming from the dismounting centers operating inside the F. A. RE. system are sent to a big recovery center and after a selection, sold to different glass plants to participate into the glass containers production.

The glass plants investigated have an energy performance variable with the cullet percentage presence as shown in Fig. 2. An average between the two considered ovens type performances was used in the calculations.

In addition to the direct energy saving coming from its presence in the vitrifiable mix, the cullet carries also as more indirect benefit as the oven efficiency is low; one of the main problems to reach the highest performance is the impurities presence in the vitrifiable mix; the F. A. RE. cullet represents a uniform quality material coming from a preferential supply system that can offer those guarantees necessary to reach the best oven energy efficiency.

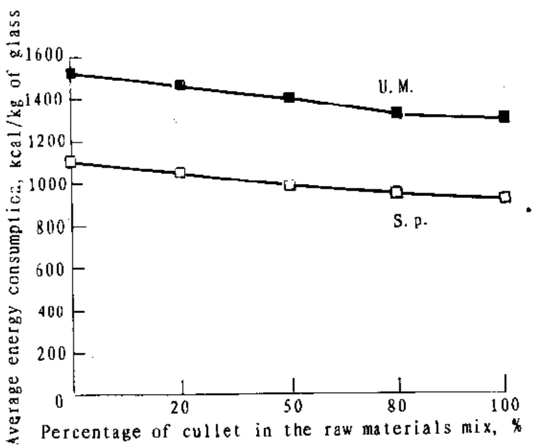

Fig. 2 Average energy consumption in Unit Melter (U. M.) and Side-port (S. p.) ovens (in kcal/kg of glass) vs. the cullet % in the raw materials mix (Ercole, 1994)

6 Energy results and considerations

The first interesting results are those reported in Table 4.

Table 4 Principal energy consumption results

Operation	Delivered energy, MJ/kg of product	Gross energy, MJ/kg of product
Raw materials necessary to produce 1 kg of float	3.6	4.2
Float glass	11.1	26.1
windshield	5	69.2
Other glasses	5.6	80.4

The considered car is a Fiat Punto(medium size car, class B) with a windshield glass of 11760g and side and rear glasses of 18140 g: to produce all the glasses of a Fiat Punto is necessary a gross energy amount of about 2270 MJ. This is an important share if compared with 760 MJ of gross energy requested by both the bumpers and with 3500—4000 MJ of gross energy necessary for a cast iron block engine assembled in the same car(Balestrini, 1994).

As far the F.A. RE. system energy saving performance is concerned, from Table 5 and Fig. 3 it is possible to say that the energy saving carried by the cullet in the glass oven plus the energy saving for the avoided raw material extraction is bigger than the energy consumption to collect and to transport the cullet itself.

Moreover the energy linked to the dismounting operations is negligible.

The average distances considered to calculate energy and emissions for the transportation to the glass containers producers are 500km from the dismounting centers to the big recovery centre and 400km from this to the plants(18t particulate trucks).

Table 5 Comparison between the energy saving of cullet use and energy consumption for its collection and transport

Cullet % in r. m. mix	Energy saving in the oven, MJ/kg glass	Energy saving due to avoided r. m. extraction, MJ/kg glass	Energy consumption for cullet collection and transport, MJ/kg glass
20	0.23	1.17	0.44
50	0.48	1.74	1.20
80	0.73	3.49	1.90
100	0.83	4.6	2

Using 40% of cullet in half-white glass production, the F.A.RE. glass could contribute to save directly (in the oven) about 1810 toe (tons soil equiv.) per year and about 7145 toe/a for the avoided raw materials extraction. The balance is (energy saving-transport energy consumption) about 4190 toe saved per year.

About the energy content of scrap, the here presented case-study could help to give rise to the discussion.

The energy analysis developed in the seventies (Boustead, 1979) has ever considered zero the intrinsic energy content of the considered scrap, assuming the existence of an available deposit of secondary materials; this is a conventional position because all the life cycle energy consumed to produce a particular good is considered lost when its utility becomes nothing.

Normally the allocation rules are used to describe a process with more than one output with different economic values: the scrap case is quite different because the final destination could be also as waste, representing therefore a further load for the " system environment".

The analysis may be based on economic considerations because when there is a demand for the scrap its price is constituted of elements corresponding to every kind of consumptions necessary to make available this material. But giving an energy and environmental load to the scrap by using economic quantities (as, for example, the ratio of the secondary material market price value to the primary material market price value) has no physical sense.

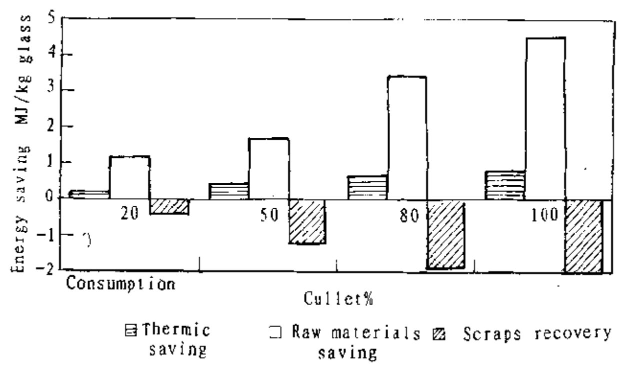

Fig.3 Comparison between the energy saving of F.A.RE. cullet use and the energy consumption for its collection and transport in glass containers production

A possible solution to this problem is to take into consideration all the operations needed by the scrap to be used again as input and to remove the virgin materials displaced by the scrap use.

This is again a moderlization of the more complex reality above mentioned, and at present is also the design technique used in the calculation model (Boustead model 2) adopted during this case-study.

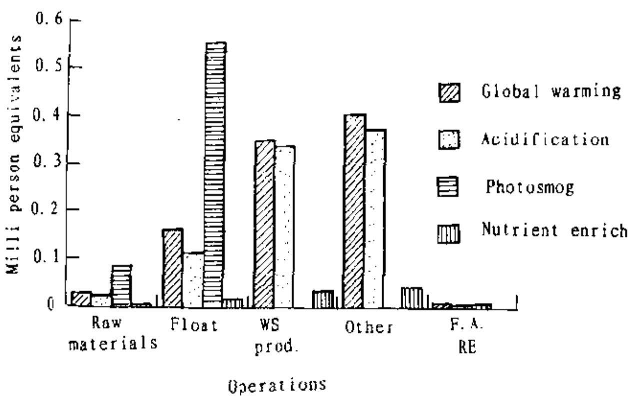

Fig.4 Normalization results of the life cycle impact assessment stage. The personal equivalents are calculated by dividing (i.e.) the CO_2 equivalents with the average annual emission of CO_2 equivalents per inhabitant in the world

7 Environmental results

Also from an environmental point of view the F. A. RE. system proves to be convenient.

Following the impact assessment methodology developed at Life Cycle Centre, Danish Technical University (Wenzel, 1994), it is possible to present an ecoprofile of the examined systems(Fig. 4).

About direct emission from the glass containers production factory, it is finally possible to say that the scrap coming from the F. A. RE. system, apart from the same benefit in the reduction of emission of a common cullet coming from the public recovery, is able to reduce SO_x emissions thanks to a controlled origin.

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