Innovazione di processo e prodotto nella filiera orzo per migliorare la qualità e la sostenibilità ambientale di alimenti e bevande

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Il *Carbon Footprint* della birra lager

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AIMS

Energy and water consumption, waste generation, and emissions to air are the main environmental issues of the brewing industry.
Several strategies have been so far proposed to reduce its impact on the global climate.

The 1st aim of this study was to develop a LCA model to estimate the CF of the industrial production and distribution of 1 hL of lager beer in different packaging formats (i.e., 66- or 33-cL glass bottles, 33-cL Al cans, 30-L stainless steel kegs) and selling units (i.e., carton, tray, or cluster-multipack).

The 2nd aim of this study was to carry out a sensitivity analysis of CF to assess the influence of different parameters (i.e., origin of raw materials and their cultivation methods, GHG emissions per kWh of electric energy generated by fossil and/or renewable sources, transportation by road or railway, etc.) to identify the most promising strategy to mitigate the GHG emissions associated to the production and distribution of the pale lager of concern.

Goal and scope

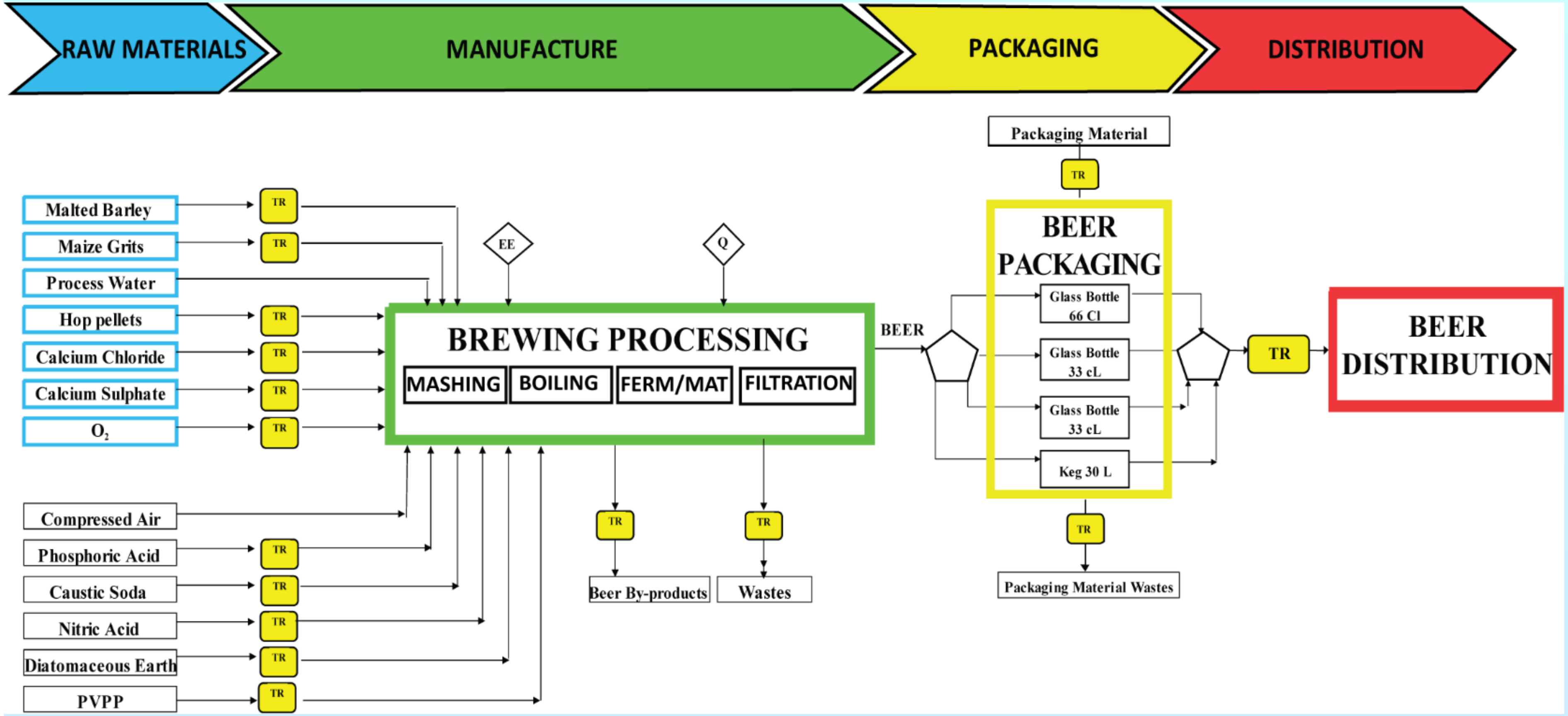
1) To develop an LCA model to assess the CF of a pale lager beer, made of malted barley, maize grits and hop pellets, produced from an Italian brewery, and consumed in Italy.

2) To identify the life-cycle hot spots.

Functional unit**:** 1 hL of lager beer packaged in different packaging formats and selling units.

System boundary

The system boundary for this study included the upstream and downstream phases.



Beer system boundary (TR = transport).

Data gathering and data quality

According to PAS 2050 (Section 7.2), the following was stated:

i) *Geographic scope*: this LCA study focused on the production, and distribution of lager differently packaged in Italy.

ii) *Time scope*: the reference time period for assessing the CF values was April 2012-March 2013.

iii) *Technical reference*: the process technology used was typical for industrial-scale lager beer processing in the reference period.

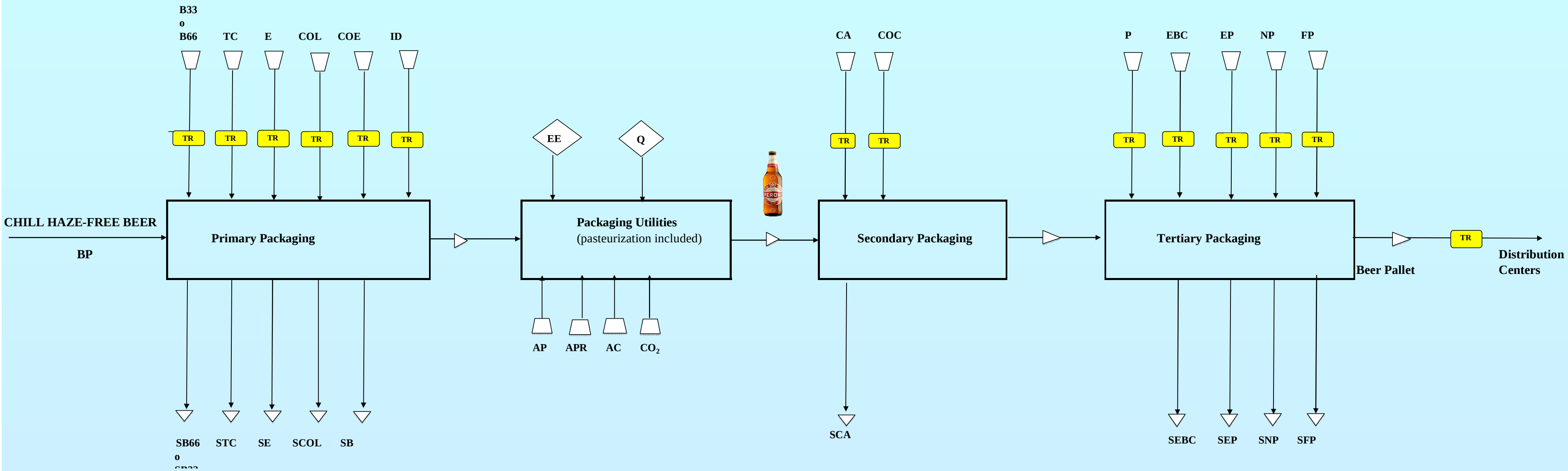
iv) *Primary data* for this PAS 2050-compliant study were collected from an Italian brewery.

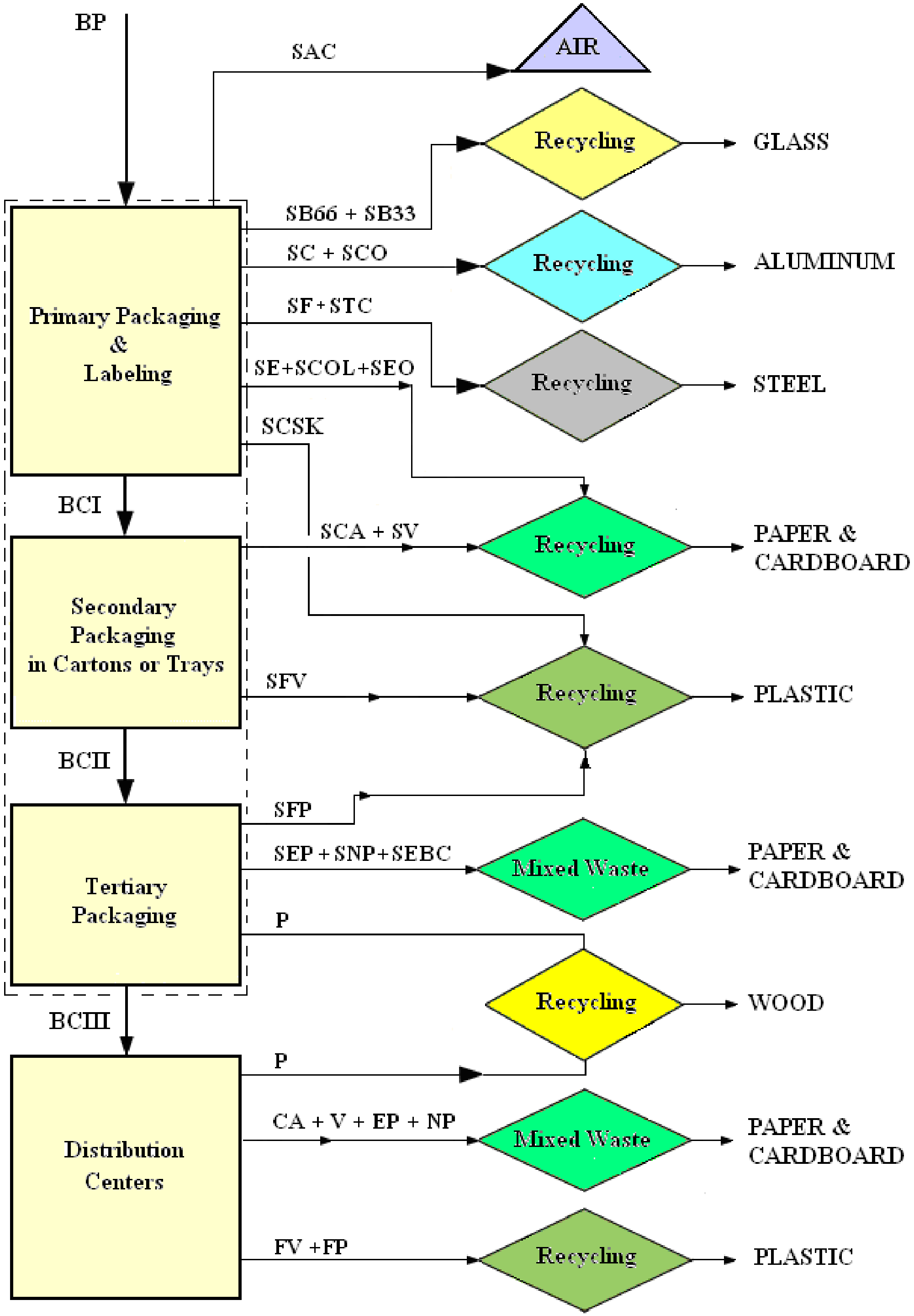
v) *Secondary data* were sourced from (ISPRA, 2012), an LCA Simapro 7.2 v.2 software (Prè Consultants, Amersfoort, NL), several databases, etc.

Specific consumption yields of *raw materials and processing aids*, *brewing coadjutants*, *detergents*, *refrigerants*, & *by-products* per hL of lager, transport means used & average distance travelled from their production site to the brewery gate.

Inventory	**Consumption Yield**	**Unit**	**Means of Transport**	**Distance [km]**
Raw materials and Processing Aids				
Barley	14.36	kg hL^{-1}	AT	236
Malted Barley	10.77	kg hL^{-1}	AT	33
Maize Grits	4.71	kg hL^{-1}	AT	608
Hop Pellets	91.60	g hL^{-1}	HRT	1509
Oxygen	1.43	g hL^{-1}	RT	91
Compressed Air	2.58	M^3 hL^{-1}	-	-
Calcium Chloride	24.78	g hL^{-1}	RT	210
Calcium Sulfate	19.91	g hL^{-1}	RT	210
Brewing coadjutants				
Diatomaceous Earth	0.112	kg hL^{-1}	RT	110
PVPP	0.110	g hL^{-1}	RT	445
Phosphoric Acid (75% w/w)	14.21	g hL^{-1}	RT	445
Detergents				
Nitric Acid (53% w/w)	17.22	g hL^{-1}	RT	445
Caustic Soda (30% w/w)	0.606	kg hL^{-1}	RT	445
Oxonia active	17.055	g hL^{-1}	RT	589
Trimeta LPC	40.256	g hL^{-1}	RT	589
Refrigerants				
Ammonia	0.052	g hL^{-1}	RT	175
Ethylene Glycol	0.956	g hL^{-1}	RT	62
Byproducts				
Spent Grains	17.44	kg hL^{-1}	RT	150
Surplus Yeast	1.45	kg hL^{-1}	RT	150

Schematic diagram of the packaging process for lager in 33- or 66-cL amber glass bottles.





Block flow diagram of **solid waste & gaseous effluent formation** during lager packaging & pallet management in tertiary packaging and distribution centers.

Life-cycle impact assessment

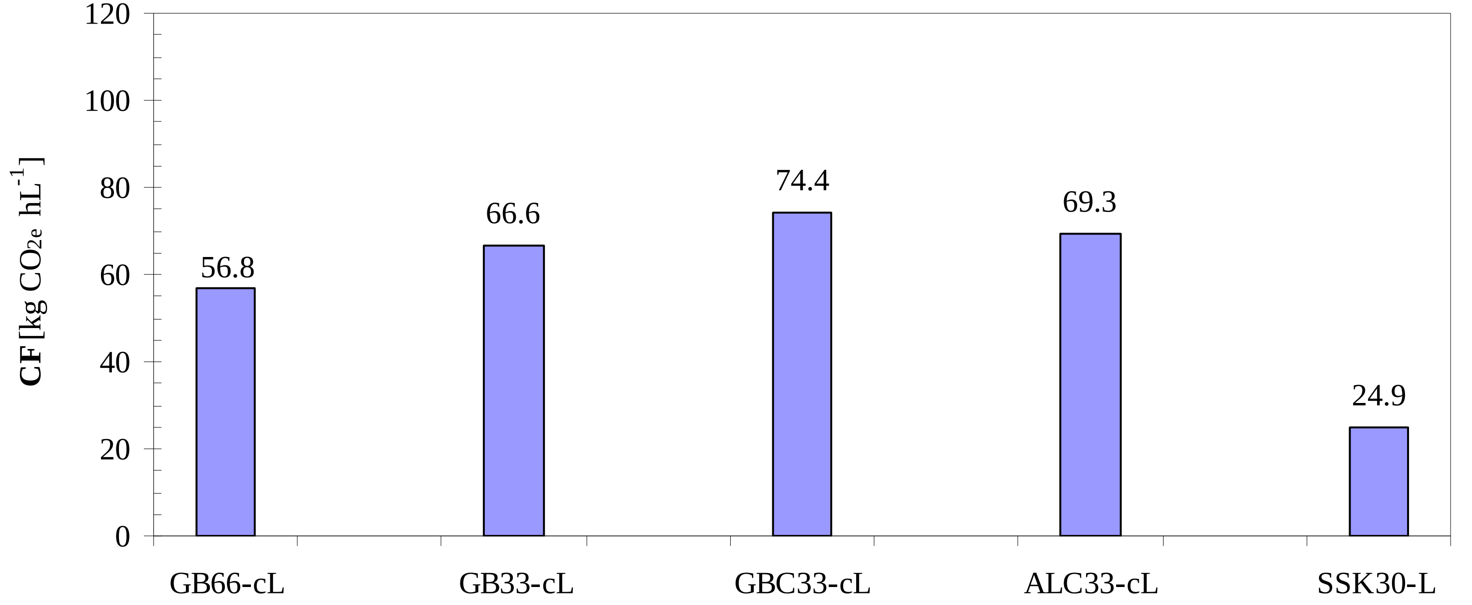
To assess the C*arbon Footprint* of 1 hL of packed beer, all GHG emissions associated to the production of raw and packaging materials, processing aids and detergents, to their transportation and that of the final product and processing wastes, to the consumption of thermal and electric energy sources, were estimated as follows

$$CF = \sum_i (\Psi_i \, EF_i) \qquad [\text{kg } CO_{2e} \text{ hL}^{-1}]$$

where

Ψ_i entity of the i-th activity parameter (i.e., mass, energy, mass-km basis)
EF_i i-th emission factor

RESULTS



CF of 1 hL of lager packaged in

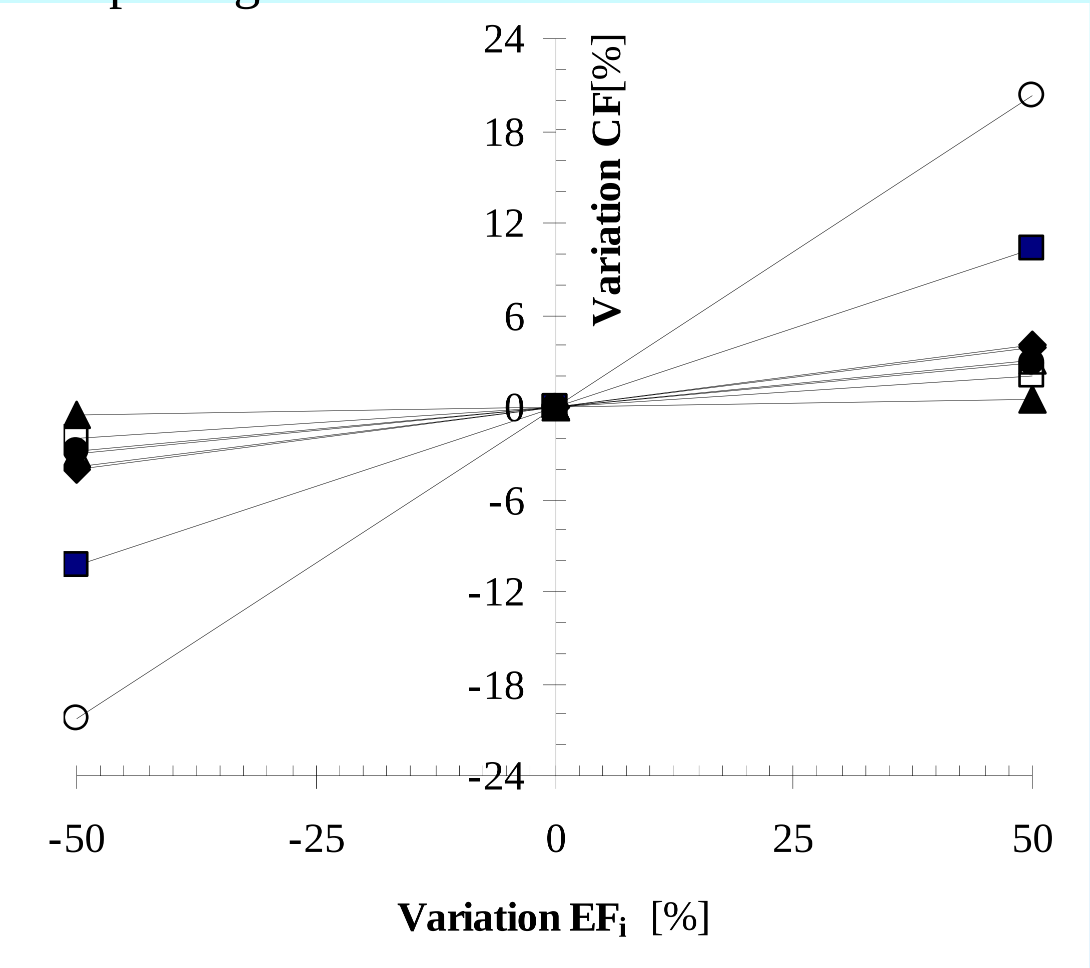
66- or 33-cL glass bottles (GB), assembled in cartons as loose or multipack (C) bottles, 33-cL Al cans (ALC), or 30-L stainless steel kegs (SSK).

Percentage contribution of the different life cycle phases to the CF of 1 hL of pale lager packed in 66- or 33-cL glass bottles (GB), the latter being assembled either loose or in cluster (C), 33-cL Al cans (ALC), or 30-L stainless steel kegs (SSK).

Life Cycle Phases		Carbon Footprint for Different Packaging Formats [kg CO_{2e} hL^{-1}]									
Final Product Primary Packaging		66-cL GB	%	33-cL GB	%	33-cL GBC	%	33-cL ALC	%	30-L SSK	%
Raw materials & processing aids	(RPM)	16.88	24	16.88	21	16.88	20	16.88	21	16.88	46
Brewing processing	(BRP)	6.26	9	6.26	8	6.26	7	6.26	8	6.26	17
Packaging materials	(PM)	33.33	48	42.19	54	48.34	56	47.55	58	1.86	5
Packaging	(PP)	2.15	3	2.14	3	2.14	2	2.07	3	2.15	6
Transportation	(TR)	9.71	14	10.67	14	12.37	14	8.09	10	9.26	25
Waste disposal	(WD)	0.58	1	0.58	1	0.58	1	0.57	1	0.61	2
Beer production excl. byproducts credits		**68.91**	100	**78.71**	100	**86.57**	100	**81.42**	100	**37.02**	100
Byproduct credits	(BPC)	-12.16		-12.16		-12.16		-12.16		-12.16	
Beer production incl. byproducts credits		**56.76**		**66.55**		**74.41**		**69.26**		**24.86**	

SENSITIVITY ANALYSIS

Effect of the percentage variation of the EF_i for **malted barley** (■), barley production site (▲), maize grits (△), **glass bottles** (○), aluminum cans (□), electric (●)& thermal (◆) energy, or means of transport of final product (◊) on the variation of CF of 1 hL of lager beer packaged in all the formats examined with respect to the basic case.



CF was more sensitive to changes in the emission factors for **glass bottles** & **barley**.

In particular, if they were reduced by 50%, CF exhibited about a 20 or 10% reduction with respect to the basic case, respectively.

Effect of different parameters on the CF of 1 hL of lager packaged in 66- or 33-cL glass bottles (GB), the latter being assembled either loose or in cluster (C), 33-cL Al cans (ALC), or 30-L ss kegs (SSK).

CF [kg CO_{2e} hL^{-1}] / **Parameter**	**66-cL GB**	**33-cL GB**	**33-cL GBC**	**33-cL ALC**	**30-L SSK**	**All formats**
Italy-grown barley	56.8	66.6	74.4	69.3	24.9	59.2
Low impact barley grown in Italy	50.3	60.1	68.0	62.8	18.4	52.8
Low impact barley grown abroad	53.3	63.1	71.0	65.8	21.4	55.8
High impact barley grown abroad	61.9	71.7	79.6	74.4	30.0	64.4
Electric energy from fossil fuels	58.0	68.0	75.8	70.7	26.1	60.5
Photovoltaic electric energy	54.0	63.4	71.3	66.0	22.1	56.4
Rail Transportation	53.2	62.6	69.20	66.2	21.5	55.5

The use of the novel PET bottles enriched with nanoclays, manufactured by Nanocor®, would

- extend the beer shelf-life up to 30 weeks thanks to their high barriers to CO_2 and O_2 migration,
- reduce the primary packaging mass from 185-290 g to **~30 g**, & the packaging material EF from ~9 kg CO_{2e} kg^{-1} for Al cans to **3-4** kg CO_{2e} kg^{-1}.

The polymer-clay nanocomposite bottles are popular with some beverage manufacturers.

In a pub the consumption of 33 cL of beer from

		g CO_{2e}	
• a glass bottle	☛	**246**	(589±161 for a small-scale brewery: Muñoz et al, 2012).
• a can,	☛	**229**	
• a keg	☛	**82**	

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According to the CF values estimated here,
the overall impact of beer consumption in Italy,
equaling **29.2 L per capita in 2013** (Assobirra, 2013),

would represent from **0.1 to 0.3 % of** the overall Italian direct GHG emissions (458.2 Tg CO_{2e}), including net GHG emissions adsorbed from land use, land-use change and forestry, in 2011 (ISPRA, 2013).

Consumers might choose a more responsible consumption of draught beer in a local pub.

Draught beer might be dispensed from beer pipelines rather than from steel or plastic kegs.

The distribution of the latter severely affects local traffic, especially in historic sites, such as Bruges in Belgium, or during beer festivals, such as the Oktoberfest in Munich in Germany.

Unfortunately, the present-day major consumption of beer is by far from glass bottles.

Conclusions

By referring to fully transparent primary and secondary data, the estimated carbon footprint (CF) of pale lager was found to vary significantly with the package used.

The CF was minimum in the case of 30-L ss kegs (~25 kg CO_{2e} hL^{-1}), for the high reuse coefficient.

The contribution of transportation was

- minimum in the case of Al cans (~8.1 kg CO_{2e} hL^{-1}) &
- maximum for three 33-cL bottle packs (~12.4 kg CO_{2e} hL^{-1}).

Conclusions

The one-factor-a-time sensitivity analysis revealed that 2 promising strategies might be applied to reduce the overall GHG emissions:

1) replacement of glass bottles and steel kegs with plastic bottles & drums;
2) use of organic barley grown locally.

The choice of resorting to wholly transparent data allows the present CF model to be reproduced by any researcher, this being one of the main principles of the scientific method.

Conclusions

Further work is needed to

- collect primary data for barley and corn agriculture, and post-consumer waste management, &
- assess the effect of the beer production scale on the carbon footprint.

Thank You for Your Attention

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