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INVESTIGATED PROCESSES LCA CHARACTERISATION IN TERMS OF CARBON FOOTPRINT – FROM CRADLE TO GRAVE APPROACH

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EXECUTIVE SUMMARY CARBON FOOT PRINT ANALYSIS

In this investigation the LCA, according to a “From Cradle to Gate” approach, for the production of a bottle intended to contain 500 ml of drinking water by mean of two different kinds of processes, has been carried out. In particular, the corresponding LCA score has been evaluated on the base of effects related to the carbon footprint.

According to the obtained results, a significantly lower environmental impact for the bottle produced by mean of the new processing methodology has been obtained, in comparison to that one produced by mean of the traditional stages.

In particular referring to the carbon foot print, we discovered that the traditional group of processes are responsible for climate changes effects amounting to $3{,}67*10^{-9}$ DALYs, while the new kind of process lea to effect amounting to $1{,}26*10^{-9}$ DALYs.

This means that, the carbon footprint (or the associated climate changes) concerned with the traditional group of processes amounts to $4{,}47*10^{-2}$ *Kg Sb-eq,* while the new process is responsible for an emission of $1{,}71*10^{-2}$ *Kg Sb-eq.* Also these outcomes witness the new process is more environmental friendly than the traditional ones.
From this data it is possible calculate the TEP related to each process considered:

Traditional bottle TEP = 9,06*10-6; new concept bottle TEP = 4,40*10-6.

The save in terms of TEP is 4,66*10-6 TEP.

All three deliverable regarding CFP have been written in one global report because are referred to the final version of the LCA analysis, which include process, material and total amount or recycled PET admitted in the process to produce a container having good mechanical properties.

1 LCA DATA and TEP – for bottle production

As already mentioned in report 1 and 2 the Implementation of the new process is responsible of a reduction of about 50-60% (depending of the variable considered) of the impact, as reported in table 1.

Table 1 Savings of the LIGHT PET Process

	Traditional Bottle	New Solution	Saving (%)
Energy (MJ_equivalent) - (CML Tool)	0,970	0,324	- 66,60
Emissions (Kg_CO_2 eq.) (GWP_100 Yr Tool)	$3,47*10^{-2}$	$1,57*10^{-2}$	- 54,76
TEP (Ecoindicator 99 Tool)	$1,67*10^{-5}$	$6,21*10^{-6}$	-62,81

The following tables represent the splitting of the contributions of each part of the process (Process and material) in terms of ECO POINTS, Energy, Emissions and TEP.

As it appears, in case of traditional system, the TEP value is split about the same contribution (50%) for the process and the Material.

Table 2 Splitting of contributions in the traditional system

TRADITIONAL SYSTEM					
	Total	**Process**	**Polymer**	**Electricity**	**Material (Polymer+ electricity)**
Eco Points (Pts) (Ecoindicator 99 Tool)	$3,45*10^{-3}$	$1,73*10^{-3}$ (rate =50,14%)	$1,39*10^{-3}$ (rate = 40,29%)	$3,18*10^{-4}$ (rate = 9,22%)	1,71*10-3 (rate= 49,86%)
Energy (MJ_equivalent) - (CML Tool)	0,97	0,39 (rate=41,24%)	0,50 (rate =51,55%)	0,07 (rate = 7,22%)	0,57 (rate = 58,97%)
Emissions (Kg_CO_2 eq.) (GWP_100 Yr Tool)	$3,47*10^{-2}$	$1,28*10^{-2}$ (rate =36,88%)	$1,76*10^{-2}$ (rate =50,72%)	$4,33*10^{-3}$ (rate = 2,48%)	$2,19*10^{-2}$ (rate=63,20%)
TEP (Ecoindicator 99 Tool)	$1,67*10^{-5}$	$8,26*10^{-6}$	$6,91*10^{-6}$	$1,49*10^{-6}$	$8,40*10^{-6}$
		(rate= 49,46%)	(rate =41,38%)	(rate = 8,98%)	(rate=50,44%)
Note: Material Contribute = Virgin – Recycled;					
Electricity = Electricity contribute due to material conditioning and not included in the bottle mere processing phases					

The new system instead in the TEP value shows less contribution of the process (33,33%) amd more of the material (66,67%). This will be and important aspect when the end of life is considered (see chapter 2).

Table 3 Splitting of contributions in the new system

NEW SYSTEM					
	Total	**Process**	**Material**	**Electricity**	**Material (Polymer+ electricity)**
Eco Points (Pts) *(Ecoindicator 99 Tool)*	$1,36*10^{-3}$	$0,55*10^{-3}$ (rate = 40,44%)	$0,49*10^{-3}$ (rate = 35,81%)	$0,32*10^{-3}$ (rate = 23,75%)	$0,81*10^{-3}$ (rate = 59,56%)
Energy (MJ_equivalent) *- (CML Tool)*	0,324	0,151 (rate = 46,61%)	0,1 (rate = 30,86%)	0,073 (rate = 22,53%)	0,173 (rate = 53,39%)
Emissions (Kg_CO_2 eq.) *(GWP_100 Yr Tool)*	$1,57*10^{-2}$	$5,43*10^{-3}$ (rate = 34,59%)	$5,98*10^{-3}$ (rate = 38,09%)	$4,29*10^{-3}$ (rate = 27,32%)	1,03*10-2 (rate = 65,41%)
TEP (Ecoindicator 99 Tool)	$6,21*10^{-6}$	$2,07*10^{-6}$ (rate = 33,33%)	$2,64*10^{-6}$ (rate = 42,51%)	$1,50*10^{-6}$ (rate =24,15%)	$4,14*10^{-6}$ (rate = 66,67%)
Note:					
- **Material Contribute = Virgin – Recycled;**					
- **Electricity = Electricity contribute due to material conditioning and not included in the bottle mere processing phases;**					

2 LCA DATA and TEP –included End of Life

If end of life step is considered a further saving in terms of eco points, energy and therefore TEP is point out.
As a first approximation, the savings you get considering the whole life cycle (including recycling) affects mainly the material. In the tables it has been highlighted that the material include both contribution of the polymer and the energy (electricity) used for drying.

Table 4 Savings considering end of life

	Traditional Bottle	**New Solution**	**Saving (%)**
Eco (Pts) (Ecoindicator 99 Tool)	$1,01*10^{-3}$	$4,79*10^{-4}$	- 52,57
Energy (MJ_equivalent) - (CML Tool)	0,426	0,225	- 47,18
Emissions (Kg_CO_2 eq.) (GWP_100 Yr Tool)	$1,46*10^{-2}$	$7,54*10^{-3}$	- 51,64
TEP (Ecoindicator 99 Tool)	$9,06*10^{-6}$	$4,40*10^{-6}$	- 51,43

Details in the end of life savings for each system are reported in tables 5 and 6.

Table 5 End of live contribution for the traditional system

TRADITIONAL SYSTEM			
	Total	**Production (Process+Material+ electricity)**	**Endo fo Life**
Eco Points (Pts) (Ecoindicator 99 Tool)	$1,02*10^{-3}$	$3,45*10^{-3}$	- $2,43*10^{-3}$ (abatement = 70,43%)
Energy (MJ_equivalent) - (CML Tool)	0,426	0,970	- 0,544 (abatement = 56,08%)
Emissions (Kg_CO_2 eq.) (GWP_100 Yr Tool)	$1,45*10^{-2}$	$3,47*10^{-2}$	- $2,02*10^{-2}$ (abatement = 58,21%)
TEP (Ecoindicator 99 Tool)	$9,06*10^{-6}$	$1,67*10^{-5}$	- $7,64*10^{-6}$ (abatement = 45,75%)

Table 6 End of live contribution for the new system

NEW SYSTEM			
	Total	**Production (Process+Material+ electricity)**	**Endo fo Life (Material)**
Eco Points (Pts) (Ecoindicator 99 Tool)	$4,80*10^{-4}$	$1,36*10^{-3}$	- $8,80*10^{-4}$ (abatement = 64,70%)
Energy (MJ_equivalent) - (CML Tool)	0,225	0,324	- 0,099 (abatement = 30,56%)
Emissions (Kg_CO_2 eq.) (GWP_100 Yr Tool)	$7,76*10^{-3}$	$1,57*10^{-2}$	- $8,08*10^{-3}$ (abatement = 51,47%)
TEP (Ecoindicator 99 Tool)	$4,40*10^{-6}$	$6,21*10^{-6}$	- $1,81*10^{-6}$ (abatement = 29,15%)

Due to the fact that in the new process material has a higher weight, the savings reported in table 4 are more significant for the new process.

APPENDIX A
INVESTIGATED PROCESSES LCA CHARACTERISATION IN TERMS OF CARBON FOOTPRINT – FROM CRADLE TO GRAVE APPROACH- PRODUCTION

A.1-Introduction

The aim of this section the determination of the environmental impact related to the new process employed for water bottles production in terms of carbon footprint. The LCA will be dealt with in terms of global warming issues and the LCA score will be given in terms of DALYs (**DALY:** Disability adjusted life year – number of year lost due to ill-health, disability or early death). It can be considered as a measure of the cumulative effects on the environment due to emission of polluting species. In this case it may measure the mentioned effects closely correlated to the emission of species responsible for Climate Changes or global warming.

As reported in the title, the analysis deals with the production of the bottle, neglecting any further issues as service life, durability, performance and end of life (from cradle to gate approach).

A.2-Results and discussion

As previously introduced, this section deals with the final LCI on the bottles produced by mean of the two kind of processes, in which the respective end of life stages have been excluded.

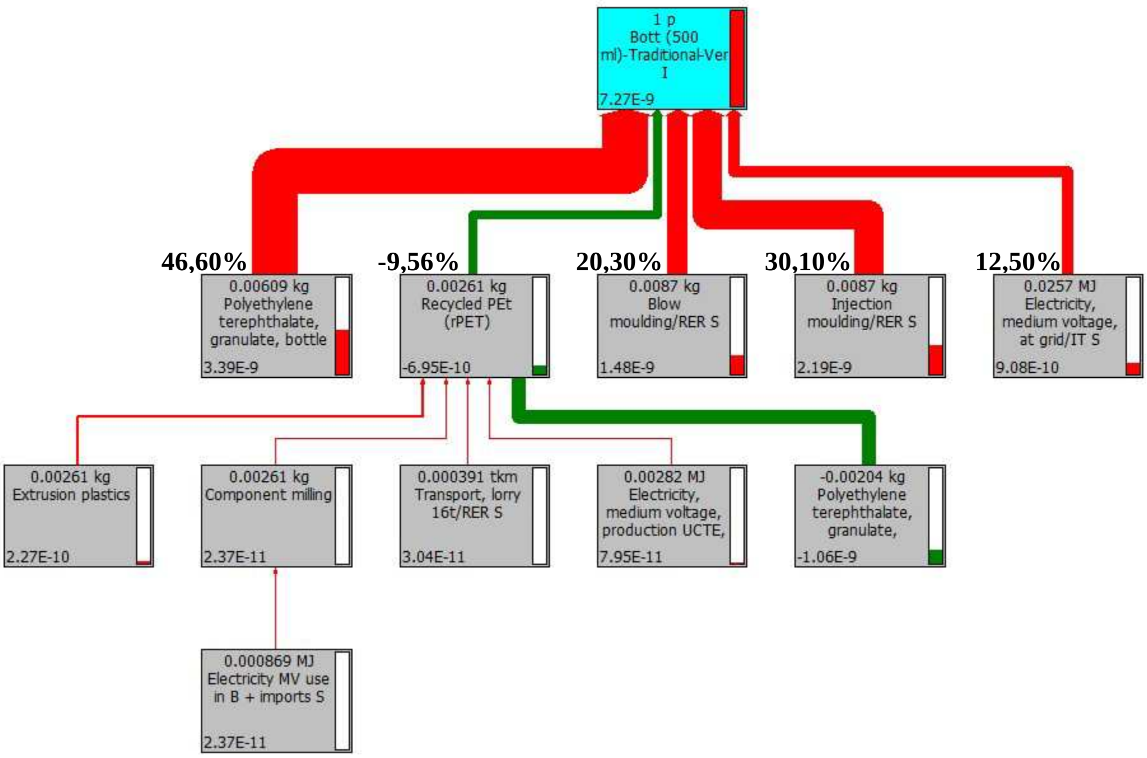

Figure A.1: *Process tree concerned with the LCA of the bottle produced through the traditional system.*

Referring to the schemes of figure A.1, the LCA score expressed in DALYs, which in this event refers to the mentioned score given in terms of climate changes issues, hence as a measure of the carbon footprint. The score for the bottle produced by mean of the traditional processes amounts to $7{,}27 \cdot 10^{-9}$ DALYs.

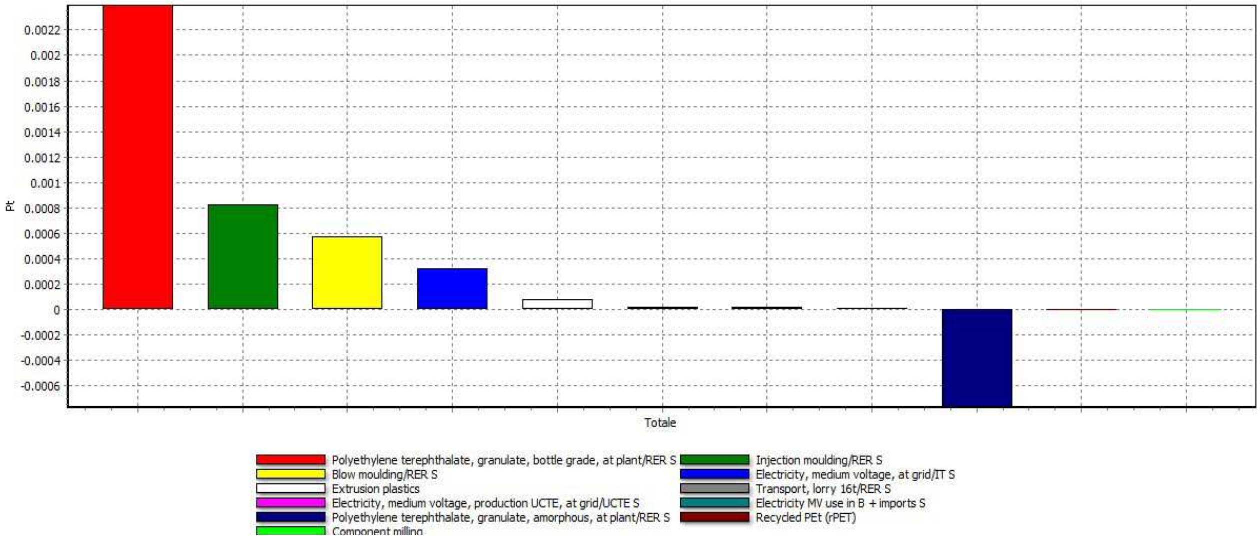

Figure A.2: *Main contributes to the whole LCA score due to each single flow for the traditional process.*

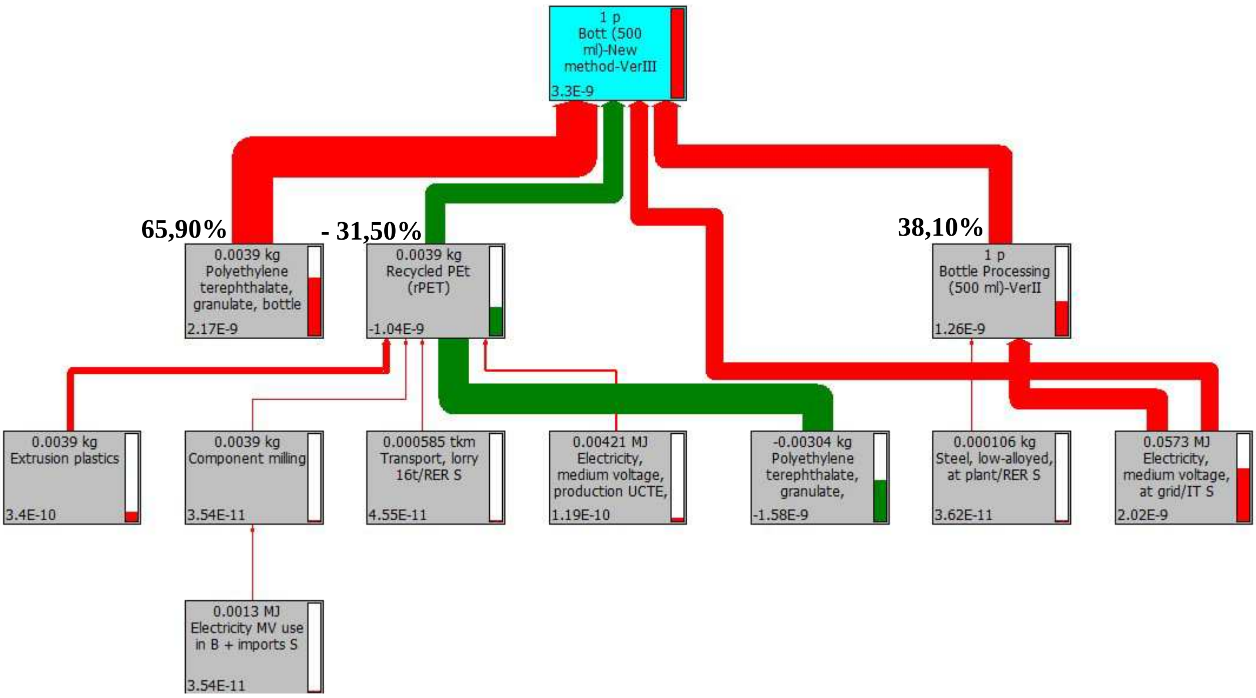

Figure A.3: *Process tree concerned with the whole LCA of the bottle produced through the new system.*

As show in the mentioned figure, about the 46,60% of the total score is due to the employment of virgin PET. About the 63% of the whole impact may be attributed to the whole range of processes involved in the bottle production (also the energy expense employed in the polymer drying has been taken into account). The employment of the recycled PET (30% in weight) allows saving the 9,56% of the impact.

The described framework is shown also in figure A.2, where each contributes (each flow) to the whole LCA score has been represented.

About the new process, as shown in figure A.3 and A.4, also in terms of carbon footprint, the LCA score, which amounts to 3,30*10^{-9} DALYs, is considerably lower than the traditional counterpart (nearly the half part).

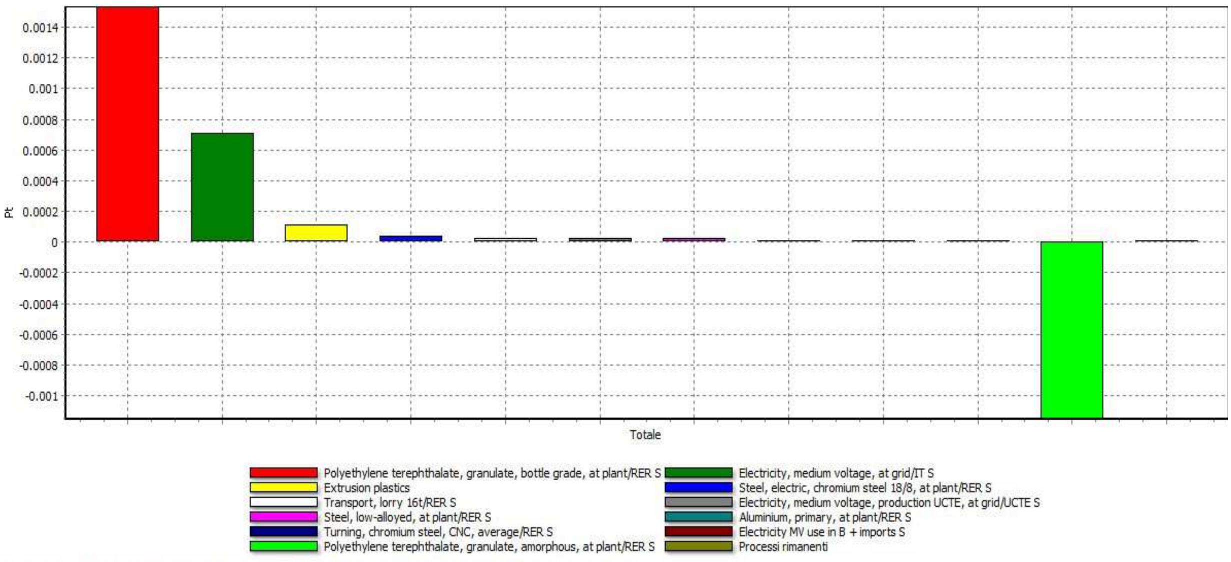

Figure A.4: *Main contributes to the whole LCA score due to each single flow for the new process.*

At this purpose, the 65,90% of the whole impact is due to the virgin PET, while the new process is responsible for another 38,10%. The employment of recycled polymer (50% in weight) allows saving the 31,50% of the whole score.

At this purpose, the traditional group of processes are responsible for climate changes effects amounting to 3,67*10^{-9} DALYs, while the new kind of process lea to effect amounting to 1,26*10^{-9} DALYs.

Finally, as shown in table 1 of the related report, the carbon footprint (or the associated climate changes) concerned with the traditional group of processes amounts to 4,47*10^{-2} *Kg Sb-eq,* while the new process is responsible for an emission of 1,71*10^{-2} *Kg Sb-eq.* Also these outcomes witness the new process is more environmental friendly than the traditional ones.

A.3-Conclusion

In this investigation the LCA, according to a “From Cradle to Grave” approach, for the production of a bottle intended to contain 500 ml of drinking water by mean of two different kinds of processes, has been carried out. In particular, the corresponding LCA score has been evaluated on the base of effects related to the carbon footprint.

According to the obtained results, a significantly lower environmental impact for the bottle produced by mean of the new processing methodology has been obtained, in comparison to that one produced by mean of the traditional stages.

APPENDIX B

INVESTIGATED PROCESSES LCA CHARACTERISATION IN TERMS OF CARBON FOOTPRINT – FROM CRADLE TO GRAVE APPROACH- END OF LIFE

B.1-Introduction

Also in this section the determination of the environmental impact related to the new process employed for water bottles production in terms of carbon footprint will be dealt with. The LCA will be carried out in terms of global warming issues and the LCA score will be given in terms of DALYs (**DALY:** Disability adjusted life year – number of year lost due to ill-health, disability or early death). As reported in the title, the analysis deals with the production of the bottle and the related end of life. Issues as service life, durability will be neglected as the related experimental data are completely missing.

B.2-Results and discussion

As previously introduced, this section the final LCI on the bottles produced by mean of the two kind of processes has been developed. The end of life stages have been taken into account for both the processes.

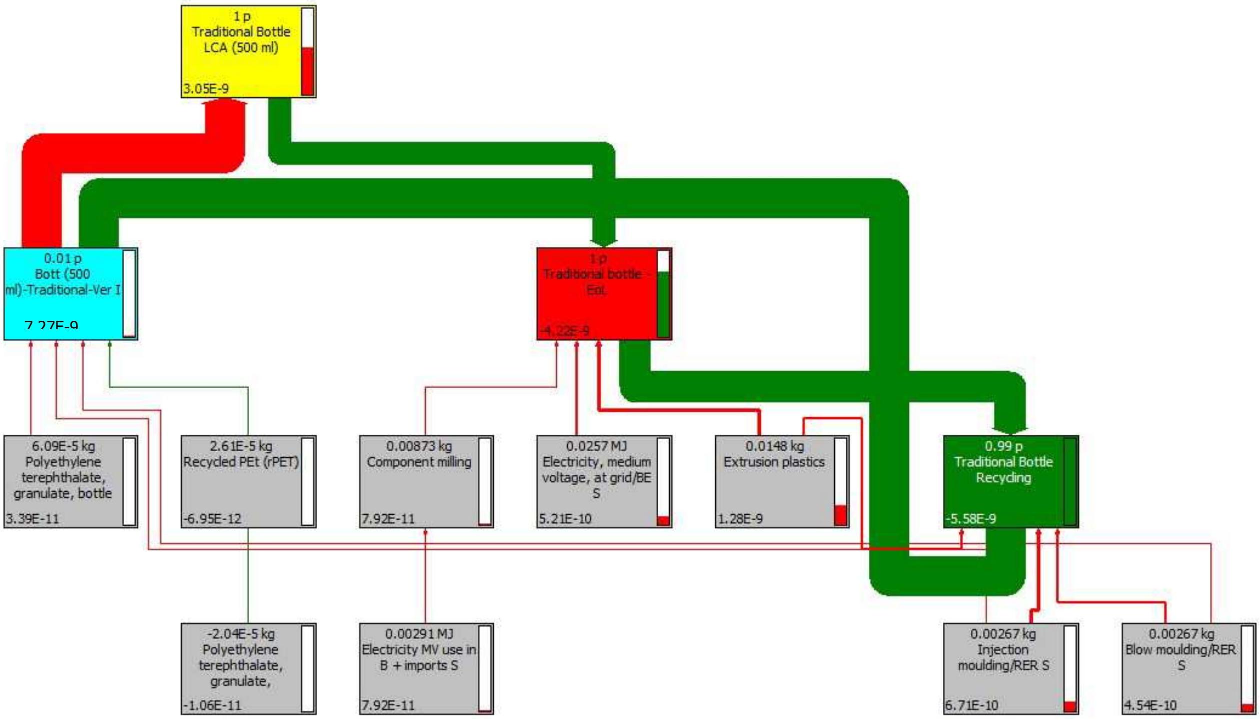

Figure B.1: *Process tree concerned with the LCA of the bottle produced through the traditional system.*

As show in the mentioned figure B.1, the total score obtained in the case of the bottle produced by mean of the traditional group of processes amounts to $3{,}09 \cdot 10^{-9}$ DALYs. About the 58% of the whole impact can be may be cut thanks to the end of life, also in terms of carbon footprint.

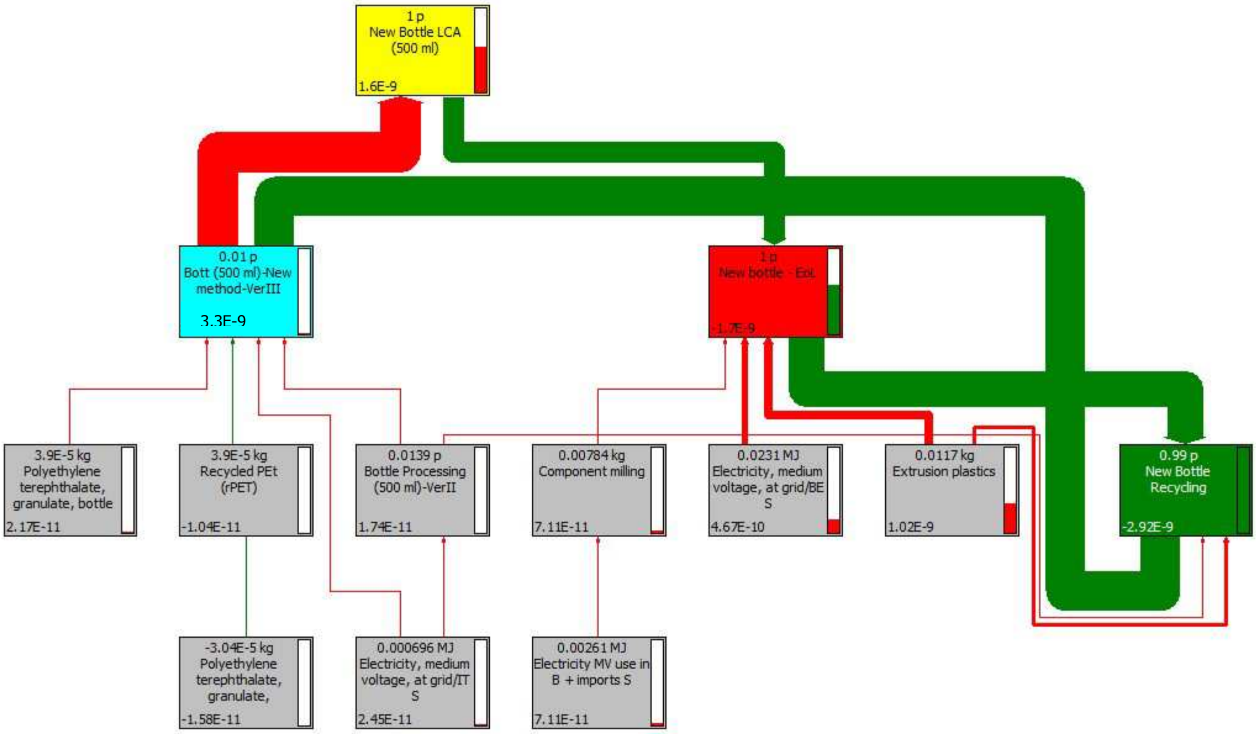

Figure B.2: *Process tree concerned with the LCA of the bottle produced through the new kind of process.*

As show in the mentioned figure B.2, the total score obtained in the case of the bottle produced by mean of the new kind of process amounts to 1,60*10^{-9} DALYs. As in the previous case, the end of life allows cutting a relevant part of the whole LCA score (about 52%).

In any case, from the point of view of emission related to climate changes issues (hence also to the carbon footprint), the complete LCA evidences that the new process leads to a considerable reduction of the environmental impact in comparison to the traditional group of processes. This reduction amounts to the 48%.

Finally, as shown in table 1 of the final report, the carbon footprint (or the associated climate changes) concerned with the traditional group of processes amounts to 2,04*10^{-2} *Kg Sb-eq,* while the new process is responsible for an emission of 1,06*10^{-2} *Kg Sb-eq.* Also these outcomes witness the new process is more environmental friendly than the traditional ones, as the reduction amounts to 48% again.

B.3-Conclusion

In this investigation the LCA, according to a "From Cradle to Grave" approach, for the production of a bottle intended to contain 500 ml of drinking water by mean of two different kinds of processes, has been carried out. In particular, the corresponding LCA score has been evaluated on the base of effects related to the carbon footprint.

According to the obtained results, a significantly lower environmental impact for the bottle produced by mean of the new processing methodology has been obtained, in comparison to that one produced by mean of the the traditional stages.