Life Cycle Assessment of an emergency lamp manufactured by the firm BEGHELLI

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ABSTRACT

This study was performed jointly by ENEA (Italian National Agency for New Technologies, Energy and Environment), Bologna and Florence Universities and the firm BEGHELLI[1]. The system function to be studied is the lighting of a room where a blackout has occurred. The functional unit is an emergency lamp manufactured by BEGHELLI, provided by a fluorescent tube and an accumulator battery with lead elements. The lamp life lasts 10 years. LCA is obtained by using the SimaPro 3.1 code and two methods: Eco indicator 95 with the normalisation weight ascribed to 10 years and a new method obtained by enclosing into the Eco – indicator 95 method some new damage categories such as some raw material depletion, solid and energy.

The results show that the accumulator battery, the structure of the lamp and the electronic board are the components with greater environmental damage and the electrical energy for use produces 31% of total damage calculated by the Eco - indicator method. The most important categories of damage produced by accumulator battery are acidification due to material production and heavy metals due to disposal treatment of lead, and the ones produced by electronic card are acidification and winter smog due to copper production.

To reduce the damage of emergency lamp some new solutions have been proposed.

Finally the characteristics to obtain emergency lamp Ecolabel have been proposed.

Keywords: Life Cycle Assessment, Emergency lamp, Ecodesign, Eco – indicator, Ecolabel, Electronic Card

1. DEFINITION OF AIMS AND BOUNDARIES OF THE STUDY.

The **goal** of the study is the evaluation of the environmental damage due to manufacturing, use and end of life of the emergency lamp produced by the firm BEGHELLI and the proposal of a new design solution to reducing the environmental damage.

The **system function** to studying is the emergency lighting of a room in which the output of electric energy ceases suddenly. The emergency lighting can be used for reserve and for safety. The function that we study is the safety of the people.

The **functional unit** is a lamp of only emergency that by the Italian law 626/94 must be used in all the public rooms. The lamp emits a luminous flux of 350 lm by means of a fluorescent tube and an accumulator battery with lead elements and can be used for 10 years.

The **system** to studying is the emergency lamp.

The **system boundaries** include raw material extraction and lamp end of life.

LCA is obtained by using the SimaPro 3.1 code[2] and two methods: Eco indicator 95 with the normalisation weight ascribed to 10 years and a new method obtained by enclosing into the Eco – indicator 95 method some new damage categories such as some raw material depletion, solid and energy.

In the LCA study the processes to producing some electronic components (electrolytic condenser, transistor, microprocessor, diode) have been simplified.

We have assumed that during the manufacturing a quantity of scraps is produced equal to the 2% of the weight of the components. For all metallic materials the recycling is considered as the waste scenario.

The data have the following characteristics:

- many data are not lied to a geographic area, other are lied to Europe and to Holland.
- When it had been possible, we have used the data extracted from the database of the code SimaPro3.1. Some new materials and processes had been created by using data from literature or obtained by manufacturing firms.
- The methods used are reproducible but do not consider all the emitted substances.
- The databases are named IDEMAT 96 and PRé.

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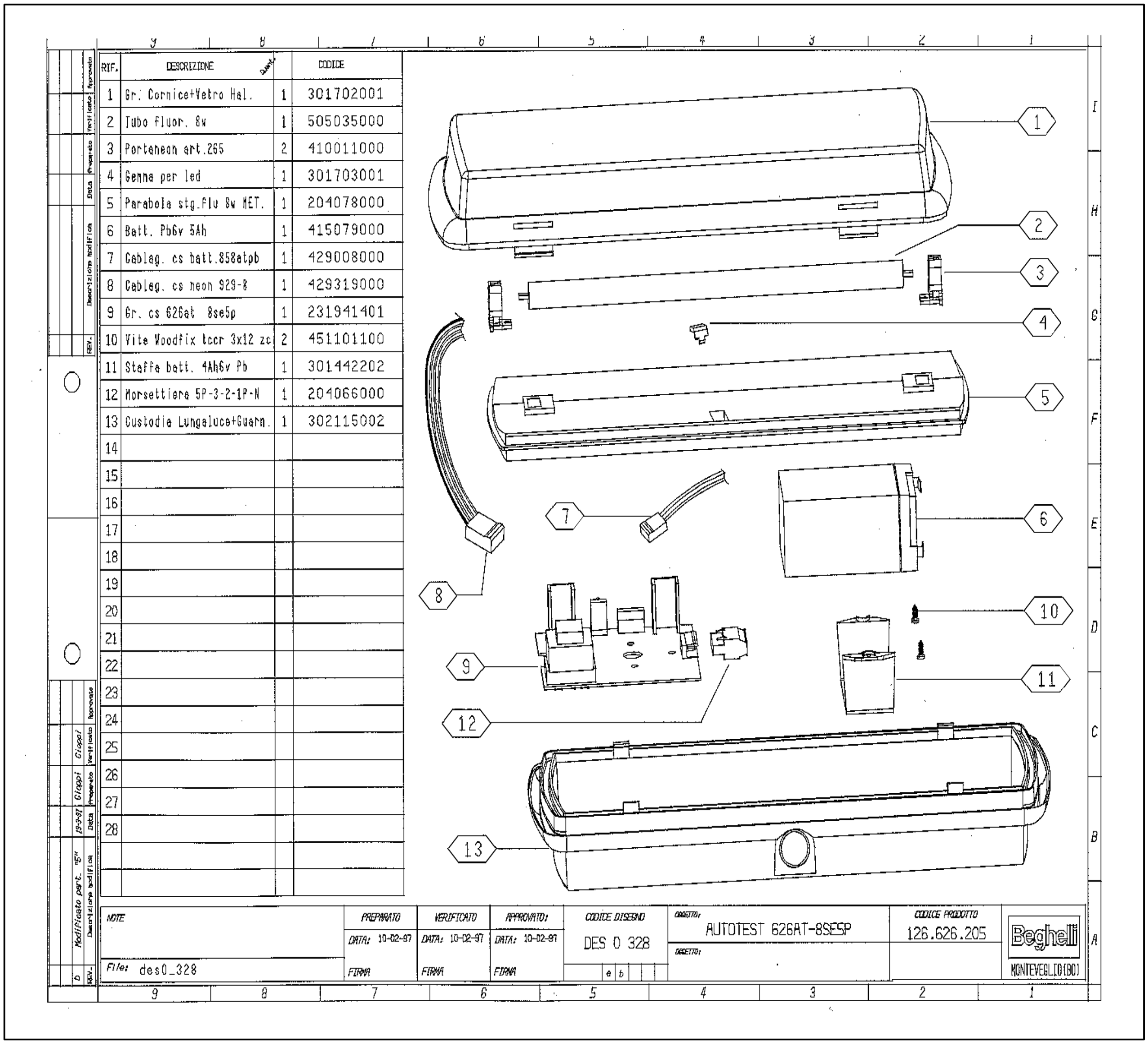
2. THE INVENTORY

The inventory of the lamp, whose components are shown in Fig.1, was executed on the basis of flow-chart printed in Fig.2.

Fig.1 The lamp components



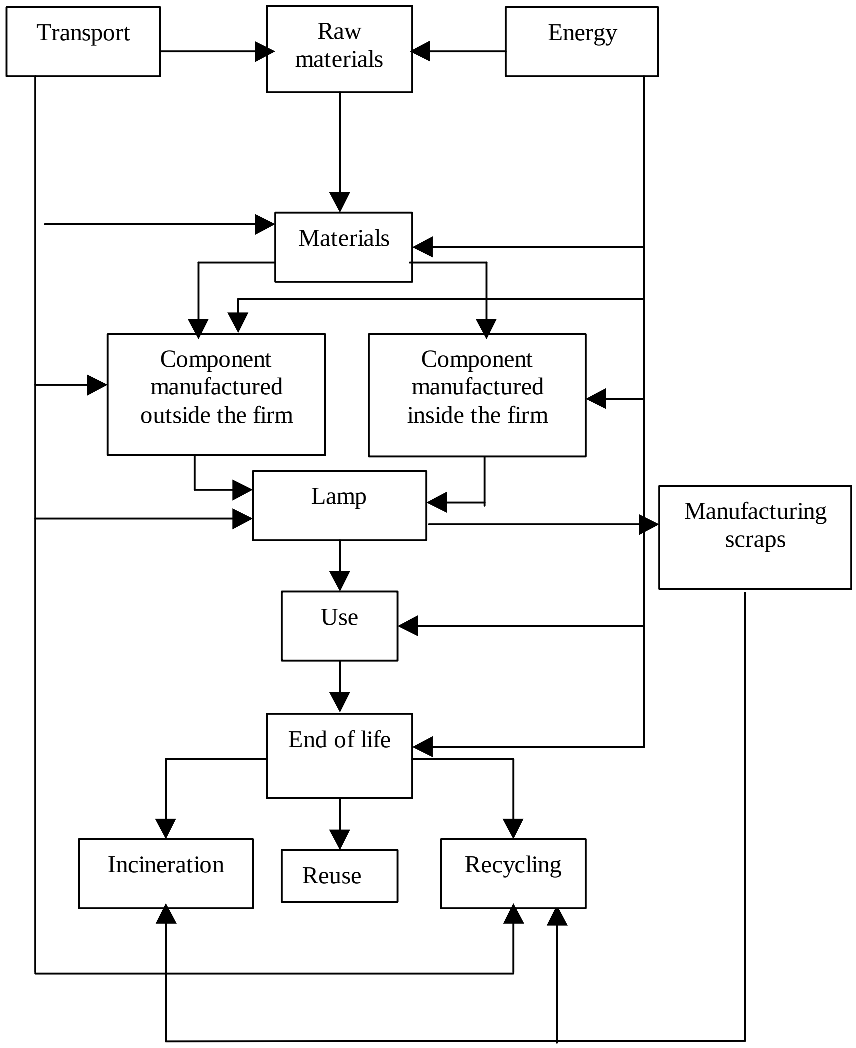
2.1 Criteria used for the inventory definition.

The criteria for the inventory definition are the following:

- we have considered the production of the materials and the transport from the material providers to the component manufacturers.
- We have considered the manufacturing of all components
- The firm BEGHELLI executes the assembling of the electronics components on the board, the injection moulding of the plastic components, the final assembly of the components, the testing and the packaging.
- Moreover we have considered the distribution of the lamp assuming that inland, international and intercontinental commerce is 85%, 5%, and 10% of the total commerce respectively.
- We have assumed that the life of the lamp is 10 years.
- The present end of life of the lamp (excluding the accumulator and the fluorescent tube) is a crushing process that allows the recycling of the principal metallic materials. In this study we have not considered the crushing process and have assumed that all the separable materials are recycled. Among the materials that are not manually separable, the plastic materials connected to the metallic ones are incinerated without energy recovery, the plastic materials constituted by not compatible polymers are incinerated with energy recovery. For the mercury and sulphuric acid we have assumed the reuse.

2.2 General description of inventory.
The lamp is formed by 13 components some of which we have arranged in the groups shown in Fig.3:

Fig.2 Flow chart of the life cycle of the lamp



- the two wiring harnesses (components 7 and 8) that connect the electronic card with the battery and the fluorescent tube respectively.
- The components 3, 4, 11 (neon holder, led support and battery bracket) that have a function of support of other components. Moreover the neon holder generates the discharge that permits the lamp ignition and the diffuser led amplifies the light of the led placed on the card.
- The components 1, 5, 10, 13 (frame and glass, parabolic diffuser, screws, pack and gasket).

The other components are: electronic card (comp.9), fluorescent tube (comp.2), battery (comp.6) and electrical connector (comp.12).
The total lamp 'life cycle' is obtained by the contribution of several different LCA:

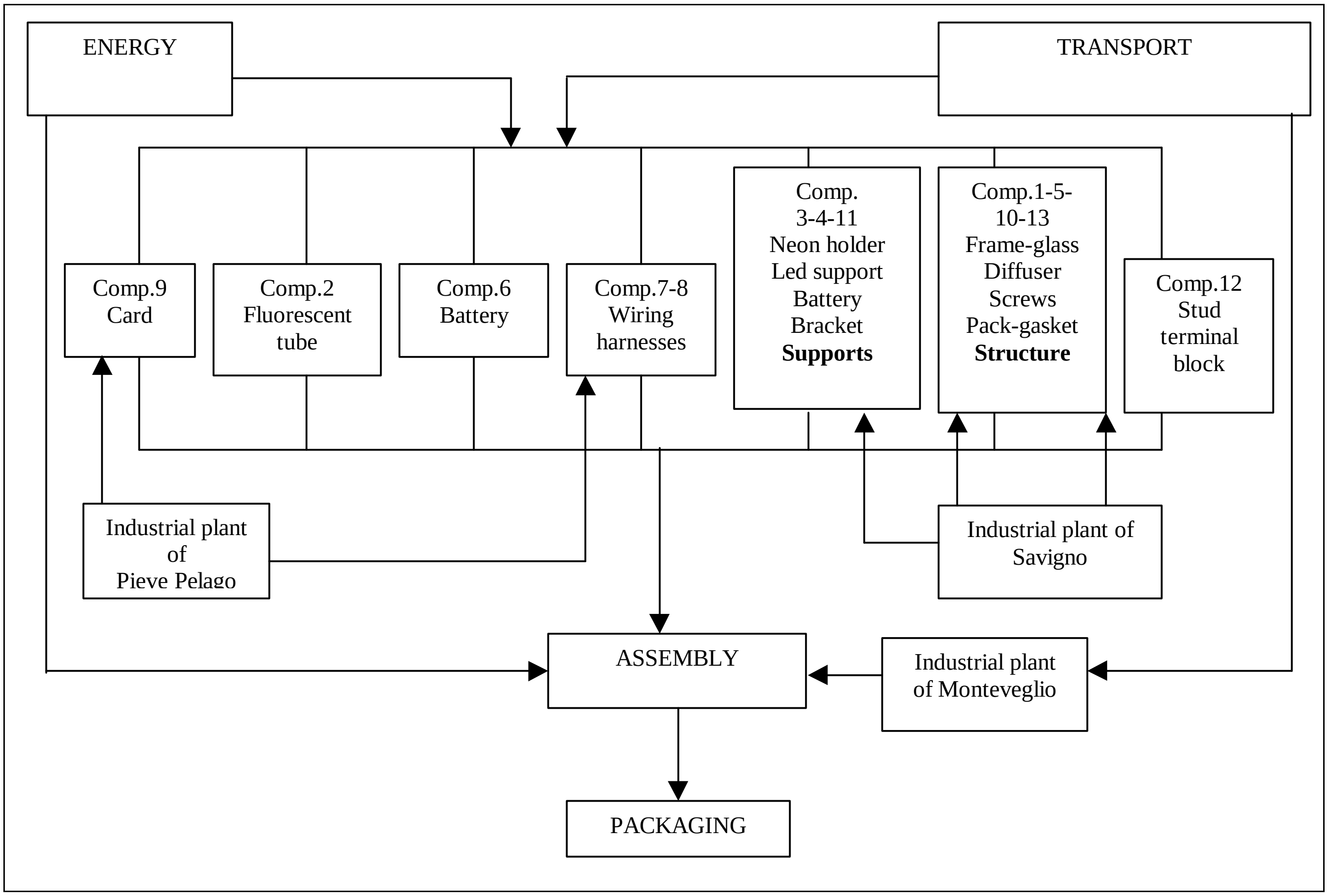
- 'life cycle' of each component
- 'life cycle' of packaging
- 'life cycle' of the electric energy for the component assembling and use
- 'life cycle' of the transports for distribution and servicing.

2.2.1 The 'disposal scenarios' of the component materials.

- For those plastic materials with 'disposal fraction' thermoplast and PVC, that are considered inseparable from the metallic ones, we have created two new 'waste treatments' obtained from incineration thermoplast and incineration PVC by removing the energy recovery. In the following cases like:
  a) the metallic materials with 'disposal fraction' non ferro
  b) the metallic materials with 'disposal fraction' Aluminium
  c) the metallic materials with 'disposal fraction' copper

we have created new 'waste treatments' in respect to those foreseen by the SimaPro 3.1 database.

Fig.3 The flow-chart of the lamp components



Tab.1 Data set for the 'waste treatment' of the lead

INPUT			
Process name	Def.Material/Fraction		
recycling leadmod	**Non-ferro**		
Amount		Un.	Comment
26003.66		**ton**	**(17000+485+8500+18.66)**
Raw materials	Amount	Un.	Comment
water	**28900**	**ton**	
Others	Amount	Un.	Comment
truck long-distance B	**0.25**	**tkm**	estimated
electr. Med. V. UCPTE	**3385258**	**kWh**	estimated energy
Energy gas	**26362875**	**kWh**	
OUTPUT			
Airborne emissions	Amount	Un.	Comment
Pb	**151.8**	**kg**	
SO2	**1578.72**	**kg**	
NO2	**15936.24**	**kg**	
NO	**537.34**	**kg**	
dust (coarse)	**607.2**	**kg**	
Waterborne emissions	Amount	Un.	Comment
Solid emissions	Amount	Un.	Comment
industrial waste	**8500**	**ton**	**scorie**
chemical waste	**485**	**ton**	**PVC and ebanite (dangerous waste)**
Avoided products	Amount	Un.	Comment
Lead I	**17000**	**ton**	**secondary production of lead**

- For the lead contained in the battery we have created a new ‘waste treatment’ shown in Tab.1 that has as ‘avoided product’ the material lead I. This treatment is obtained by literature[3].
- The sulphuric acid, used as electrolyte of the battery, we have assumed that the 90% is reused and the 10% is treated and disposed as toxic waste.
- For the mercury vapour we have assumed that the 20% goes out of the tube during the lamp use and the 80% is reused.

2.2.2. The transports.

We have considered that:

- the transports for the production of the materials are included in the ‘materials’.
- The transports of the commercial components, assembled in the plants BEGHELLI, are included in the ‘life cycles’ of the components.
- The transports for the lamp distribution, by truck in Italy and in Europe, by ship for going to America, are considered in the ‘life cycle’ of the lamp.
- The transport for servicing is considered in the ‘life cycle’ of the lamp.

2.2.3 The energy.

We have considered that:

- the energy for the production of the materials and components is considered in the ‘materials’ and in the ‘processes’.
- The energy for the assembling (direct use) of the components, 3.03 min working time, is considered in the ‘life cycle’ of the lamp and is calculated as 0.391 kWh.
- The energy for indirect use (for example lighting and heating of plants) during the assembling of the components is considered in the ‘life cycle’ of the lamp and is calculated like 0.255 kWh.
- The energy of the use of the lamp is considered in the ‘life cycle’ of the lamp and is obtained as 4.406 kWh.

2.2.4 The new processes.

We have created the following new processes in respect to those present in the SimaPro 3.1 database:

- baking of the electric transformer.
- Baking for sintering of the ferrite of transformer and inductor.
- Baking for sintering of the carbon resistance of the electronic card.
- Production of the mercury.
- Metalization of the parabolic diffuser (Tab.2)
- Manufacturing of the printed circuits of the board of the card
- Welding of the electronic components on the printed card (Tab.3).

For the phosphatizing of the fluorescent tube we have used the ‘process’ phosfating (Fe, s)

Tab.2 Data set of the process of metalization of the parabolic diffuser.

INPUT			
Raw materials	Amount	Un.	Comment
Others	Amount	Un.	Comment
furnace gas	**0.006**	**MJ**	**baking at 60°C of the plastic support**
furnace gas	**0.0018**	**MJ**	**60°C temperature keeping**
electr. Med. V. UCPTE	**0.0333**	**kWh**	**1 kW for 120 sec (metalization)**
electr. Med. V. UCPTE	**0.05**	**kWh**	**1 kW for 180 sec (polymerization)**
OUTPUT			
Airborne emissions	Amount	Un.	Comment
Waterborne emissions	Amount	Un.	Comment
Solid emissions	Amount	Un.	Comment
Main products	Amount	Quantity	Un.
metalization Al	**2.2457**	**Mass**	**g**
Pct. Sub-category			
100 Non ferro			
Avoided products	Amount	Un.	Comment

Tab.3 Data set of the process of card welding

INPUT			
Raw materials	Amount	Un.	Comment
Others	Amount	Un.	Comment
electricity Italy	**0.0614**	**kWh**	
Lead I	**1.591**	**g**	**4.3g*0.37**
Tin I	**2.709**	**g**	**4.3g*0.63**
OUTPUT			
Airborne emissions	Amount	Un.	Comment
Waterborne emissions	Amount	Un.	Comment
Solid emissions	Amount	Un.	Comment
Main products	Amount	Quantity	Un.
Card welding	**4.3**	**Mass**	**g**
Pct. Sub-category			
100 others			
Avoided products	Amount	Un.	Comment

3 LCA OF LAMP CALCULATED BY ECO-INDICATOR 95 EUROPE G METHOD

In the Eco-indicator 95 method the weights of normalisation are divided for a factor 10 for taking in account the life time of the functional unit (lamp).

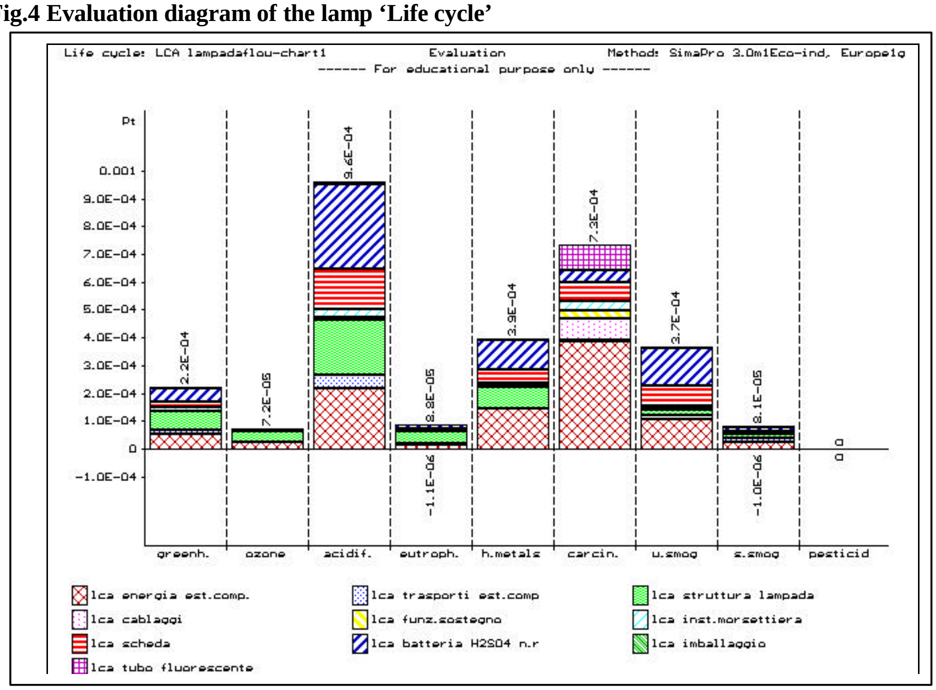
3.1 Evaluation.

In Tab.4 and Fig.4 are reported the principal results of the evaluation.

Tab. 4 'Life cycle' of the lamp

LCA COMPONENTS	NAMES OF LCA COMPONENTS	N°	DAMAGE [mPT] by Eco-indicator 95	DAMAGE [mPT] by Eco-indicator 95 modified
Energy for the lamp use	lca energia est.comp	1	967	1039
Transport of the lamp	lca trasporti est.comp	1	96.1	98.1
Structure	lca struttura lampada	1	465	1616
Wiring harness	lca cablaggi	1	94.2	105
Support	lca funz.sostegno	1	38.3	69.2
Stud terminal block	lca inst.morsettiera	1	101	197
Card	lca scheda	1	366	828
Battery	lca batteria	2	666	1875
Packaging	lca imballaggio	1	23.4	30.5
Fluorescent tube	lca tubo fluorescente	1	98.8	102
Total lamp			2918	5964

Fig.4 Evaluation diagram of the lamp 'Life cycle'



From the analysis of the results we can see that:

- The total damage is 2918 μPt using the first method
- The damage due to energy for the lamp use is 967 μPt.
- The damage for the component production is 1921.9 μPt
- The most dangerous components are: the battery that has a life of 5 years (666 μPt), structure (465 μPt) and the card (366 μPt).
- The plastic components produce a damage greater than the metallic components because the end of life of the plastic materials is more dangerous than the one of the metallic materials.

The damage categories with the most great values of damage are:

- <u>acidification</u> (960 μPt) due chiefly to lead production and electric energy for the lamp use
- <u>carcinogenic</u> (730 μPt) due chiefly to electric energy for the lamp and to processes to obtain fluorescent tube and card
- <u>heavy metals</u> (390 μPt) due chiefly to electric energy for the lamp use and to waste treatment of battery.

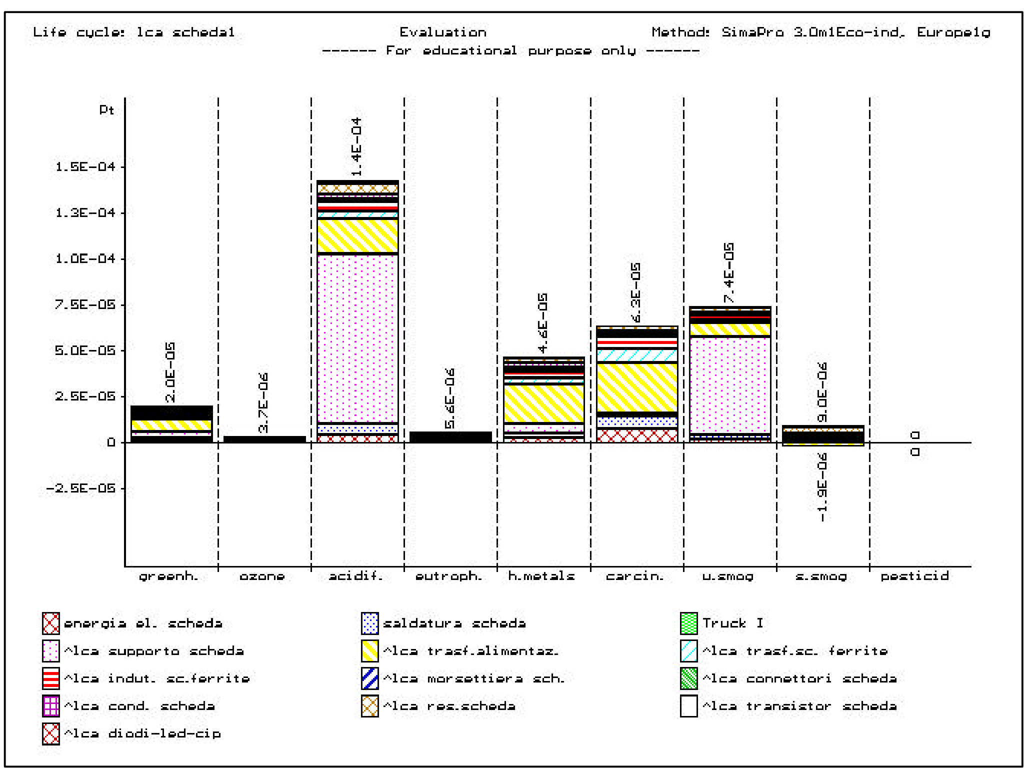
3.2 Evaluation of the card

Tab. 5 and Fig. 5 show the damages of the card and of its components.

Tab.5 The damage of the card components.

LCA COMPONENTS	NAMES OF LCA COMPONENTS	N°	DAMAGE [mPt] by Eco-indicator 95
Support	lca sup scheda mod	1	156
Electrical transformer	lca trasf.alimentaz.	1	84.6
Ferrite transformer	lca trasf.sc. ferrite	1	19.0
Ferrite inductor	lca indut. sc.ferrite	1	21.4
Electrical connector	lca morsettiera sch.	1	5.50
Connectors	lca connettori scheda	1	4.03
Condensers	lca cond. scheda	1	8.04
Resistance	lca res.scheda	1	18.0
Transistor	lca transistor scheda	1	4.26
Diodes – led - cip	lca diodi-led-cip	1	2.26
Trimmer	lca trimmer scheda	1	3.45
Electric energy	Energia el. scheda	1	18.7
Welding card	Saldatura scheda	1	20
Transports	Truck I	1	0.26
Total card			366

Fig.5 The diagram of the LCA evaluation of the card components.



From the results we can see that the components that produce the most damages are the card support (acidification and winter smog) and the electrical transformer (carcinogenic and heavy metals).

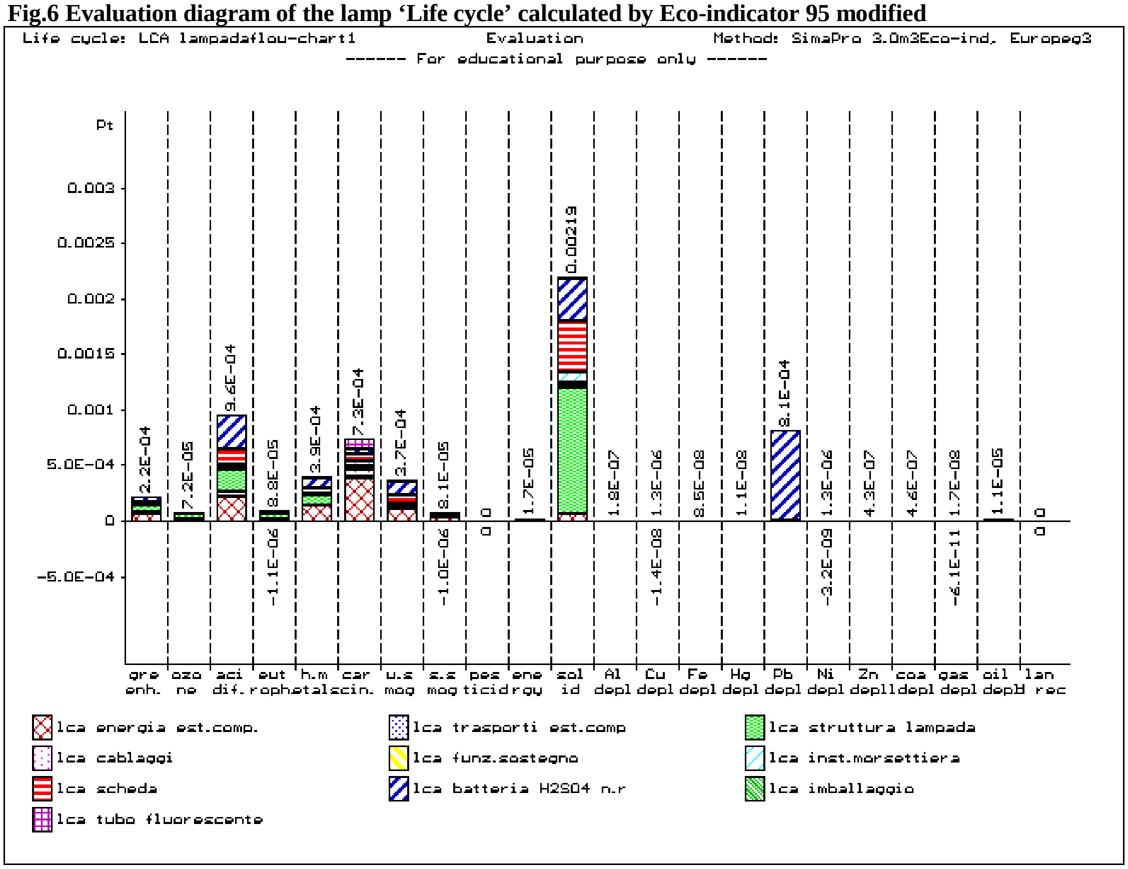
4 LCA OF LAMP WITH ECO-INDICATOR 95 EUROPE G METHOD MODIFIED.

The Eco-indicator 95 was modified by introducing some new damage categories related to depletion of minerals (Al, Cu, Fe, Hg, Ni, Pb, Zn) and fossil fuels (coal, gas, oil), by considering also the normalisation and the evaluation for solid and also the evaluation for energy.

4.1 Evaluation.

Tab.4 (last column) and Fig.6 show the principal results of the evaluation of the 'life cycle' of the lamp.

Fig.6 Evaluation diagram of the lamp 'Life cycle' calculated by Eco-indicator 95 modified



From the results we can see that the greater damages of the new damage categories are:

- 2190 µPt for solid due mainly to the structure
- 810 µPt for Pb depletion due mainly to the battery.

It has to be noted that this second method permits to put in evidence the importance of the above mentioned categories that in the first method do not appear.

5 COMPARISON WITH MATERIALS AND PROCESSES THAT PRODUCE A DAMAGE EQUAL TO THE ONE OF THE LAMP.

By Eco-indicator 95 method we have calculated the quantities of materials, processes, energies and transports that produce the damage of the lamp as 2918 µPt. From these results we can see that the studied lamp produces in 10 years the same damage of a refrigerant with a capacity of 250 l during 11.5 day of running, of 5 cycles of a washer machine with a power of 1.5 kW, of 2.5 heating of 80 l of water to 60 °C by means of an electric boiler, of the production of 145.5 kg of paving tiles, of 8.5 kg of iron and of 13 kg of aluminium.

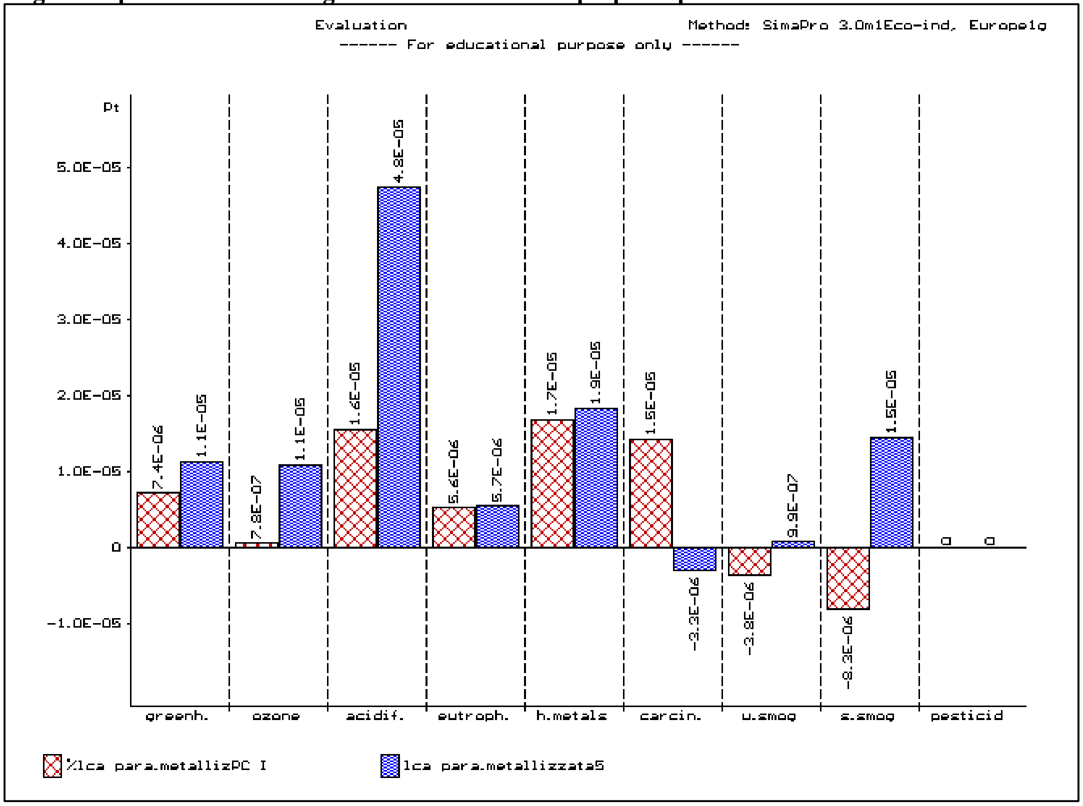
6 PROPOSALS TO REDUCE THE LAMP DAMAGE.

The LCA study has permitted to determine some modifications of the lamp design that can decrease its environmental damage. Here we report some modifications among those studied.

6.1 Replace of materials and processes.

- To separate different plastic materials we propose to use a separable **gasket**. With this modification the end of life of the **sheath** becomes the recycling of the sheath and the incineration of the gasket.
- To recycle the plastic material of the **parabolic diffuser** we propose to replace a metalization process with a foil of aluminium pinned by 4 dog clutches on the parabolic diffuser. With this modification also the aluminium can be recycled. We propose also to replace the material of the parabolic diffuser (ABS) with PC. The Fig.7 shows the comparison of the damages due to the present parabolic diffuser (106 µPt for lca para.metallizzata) and the proposed one (48.9 µPt for lca para.metallizzPCI) parabolic diffuser.

Fig.7 Comparison of the damages of the actual and the proposed parabolic diffusers.



- The European directive WEEE foresees the exclusion of the lead and bromine within the year 2004. We propose to replace the SnPb alloy used for the welding to fix the electronic components on the **card** support with the alloy 77.2Sn/20In/2.8Ag.
- To reduce the amount of materials necessary for the card we propose to use the SMD technology for assembling the electronic components on the board.
- To reduce the consumption of electric energy we propose the following modification to the **card**:
  1. use of transistors 'Mosfet' (electronic ballast) with a greater efficiency: energetic saving of 10%
  2. Use of a commutation governor rather than a linear governor: energetic saving of 8-10%
  3. Use of a transformer with fixed foils rather than that with welded foils: energetic saving of 15-20%
  4. Use of a photoelectric cell to check the lighting of the room during the diurnal hours when the natural light makes useless the ignition of the lamp.
  5. Use of smaller electronic components suitable at SMD technology that have lower dissipation.

7. INDICATIONS FOR THE DEFINITION OF THE ECOLABEL OF THE LAMP.

From the LCA study of the lamp we can present some indications to get of the lamp ecolabel. It is therefore necessary to define:

1. the upper limit of the consumption of electric energy.
2. The limit of amount of mercury in the fluorescent tube.
3. The limit of lead used for the welding the components to the card.
4. The procedure to apply the design for Disassembly technique.
5. The lamp life.

References

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