# LCA EXPERIENCE IN THE FIELD OF RECYCLING OF PLASTICS FROM ELECTRONIC WASTE

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## ABSTRACT

Conservative estimates of world population ad economy growth foresee a doubling of figures by the year 2050. This development will cause a dramatic rise in the demand for complex industrial products, in particular electronics and cars, accompanied by an increase in the consumption of natural resources as well as impacts to the environment in a life-cycle perspective. From this point of view, the goal of a sustainable development can be reached by a life-cycle thinking approach, according to a vision in which a product should be designed taking into account all its five life cycle phases: pre-production (raw material extraction phase), component manufacturing (production phase), distribution/transport phase, use phase and end of life scenarios. And this is the goal of the WEEE Directive, in force from the beginning of 2003, for which end of life of products assumes a strategic position in a life-cycle context especially for products with a limited life-span (Electrics&Electronics). This paper focuses on plastics recycling from E&E waste, that through the comparison of some technologies by a Life Cycle Assessment (LCA) point of view.

## INTRODUCTION

Manufacturing of electronic and electric equipments (E&E) is one of the fastest growing industries and the amount of E&E waste has increased to about 6 million tons per year in the European Union at the end of last century with an estimated increment of 3-5% per year (Figure 1).

**Figure 1 – Increment of electronic waste in UE**

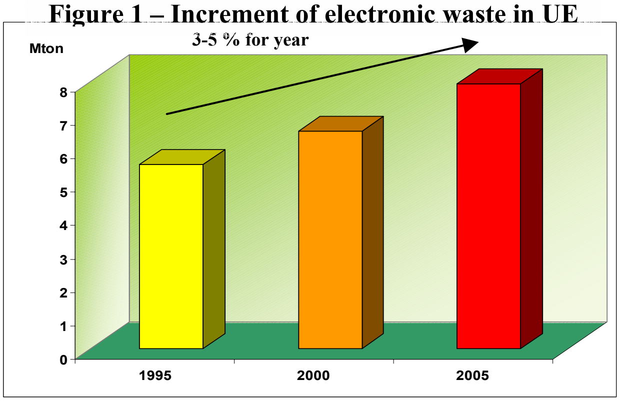
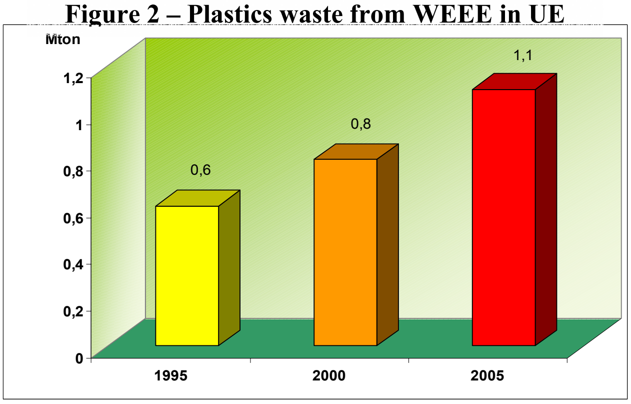



**Figure 2 – Plastics waste from WEEE in UE**




In the E&E sector, plastics have become a key to innovation and they are increasingly the material selected for brand new products: in 1980 plastics made up 15% by weight of all E&E and in 2000 this quantity had risen to 20%. As the amount of electronic waste grows, the amount of plastics waste increases too, as shown in Figure 2. For this reason, the WEEE Directive goals are to promote reuse, recycling and other forms of recovery of materials and to minimise the risks and impacts to the environment associated with the treatment and disposal phases at the end of life of these equipments, with particular regard to plastics and metals.

At present, plastics recycling processes are critical since polymers for electronic applications often contain additives, such as heavy metals and flame retardants. Development of plastics with environmentally friendly additives is going on and the use of LCA approach is considered strategic in this area, where the methodology may be used to support management strategies with particular attention to the choice of alternative processes.

**WEEE and LCA**

The purpose of the EU WEEE Directive (*Waste Electrical and Electronic Equipment* – 2002/96/EC), that entered into force on 27 January 2003, is, as a first priority, to improve the environmental performance of all operations involved in the life cycle management of these equipments, with particular attention to those operators directly involved in the end of life phase. In detail, as far as concern treatment technologies, member States shall ensure that, by 31 December 2006, the rate of recovery will be increased to a minimum of 70% by an average weight per appliance and component as well as materials and substances reuse and recycling shall be increased to a minimum of 50%. These objectives should promote an incentive to design and produce E&E equipments easier to be recovered and, in the meantime, to set up new processes to treat and recycle WEEE.

For these reasons, the LCA approach may be considered an important issue to plan design technologies both at manufacturing and at end of life treatment operations.

**PLASTICS RECYCLING TECHNOLOGIES**

In general, plastics recycling technologies can be subdivided into three main categories: mechanical, chemical and energy recovery.

Mechanical recycling processes consist in material to material transformation and the techniques are based on mechanical and, if necessary, thermal treatments. Usually, starting from thermoplastic polymers, granulates suitable for manufacturing are obtained whereas thermosetting polymers are commonly milled to be used as inert filler for plastic materials. This recycling methodology is mainly adopted when plastic wastes are homogeneous.

Chemical recycling processes are based on wastes chemical transformation through which it is possible to obtain monomers suitable for plastic materials production. As far as this recycle method is concerned, the main available technologies are:

- pyrolysis;
- hydrogenation;
- gasification.

Energy recovery consists in the re-use of feedstock energy contained in wastes. Since plastics have a net heat value of about 35-40 MJ/kg, the recovery of this energy through combustion processes for civil and industrial aims is considered strategic.

In particular, as far as concern WEEE treatment, thermal processes are one of the most attractive approach of recycling enabling recovery of bromine, monomers and precious metals. However, plastics wastes from electrical and electronic equipment often contain heavy metals and brominated aromatics as fire retardants, therefore one of the most relevant drawback in dealing with thermal treatments of WEEE is the production of halogenated dibenzodioxins and dibenzofurans. Environmentally friendly fire retardant systems are currently under developed to substitute halogen based systems and to move downward the content of halogen in forthcoming WEEE; however, waste now collected as well as those in the next future still contains a relatively large amount of brominated fire retardants. For this reason, many techniques commonly used for recycling, as mechanical recycling, foundry operations and incineration do not fit or are in conflict with the rising standards imposed by EU Directive: at present, 90% of used electrical and electronic equipment is incinerated or landfilled without any pre-treatment.

## ENVIRONMENTAL LOAD OF DISPOSAL/RECYCLING TECHNOLOGIES

Four different scenarios for waste routes from E&E equipment are going to be compared by means of life-cycle perspective, with the aim of calculating the environmental impacts associated with the treatment of 1 kg of electronic scrap: landfill disposal, incineration plant, Knudsen recycling process and Haloclean pyrolysis technology (Figure 3 and 4).

**Figure 3 –** End-of-life scenarios implemented for WEEE

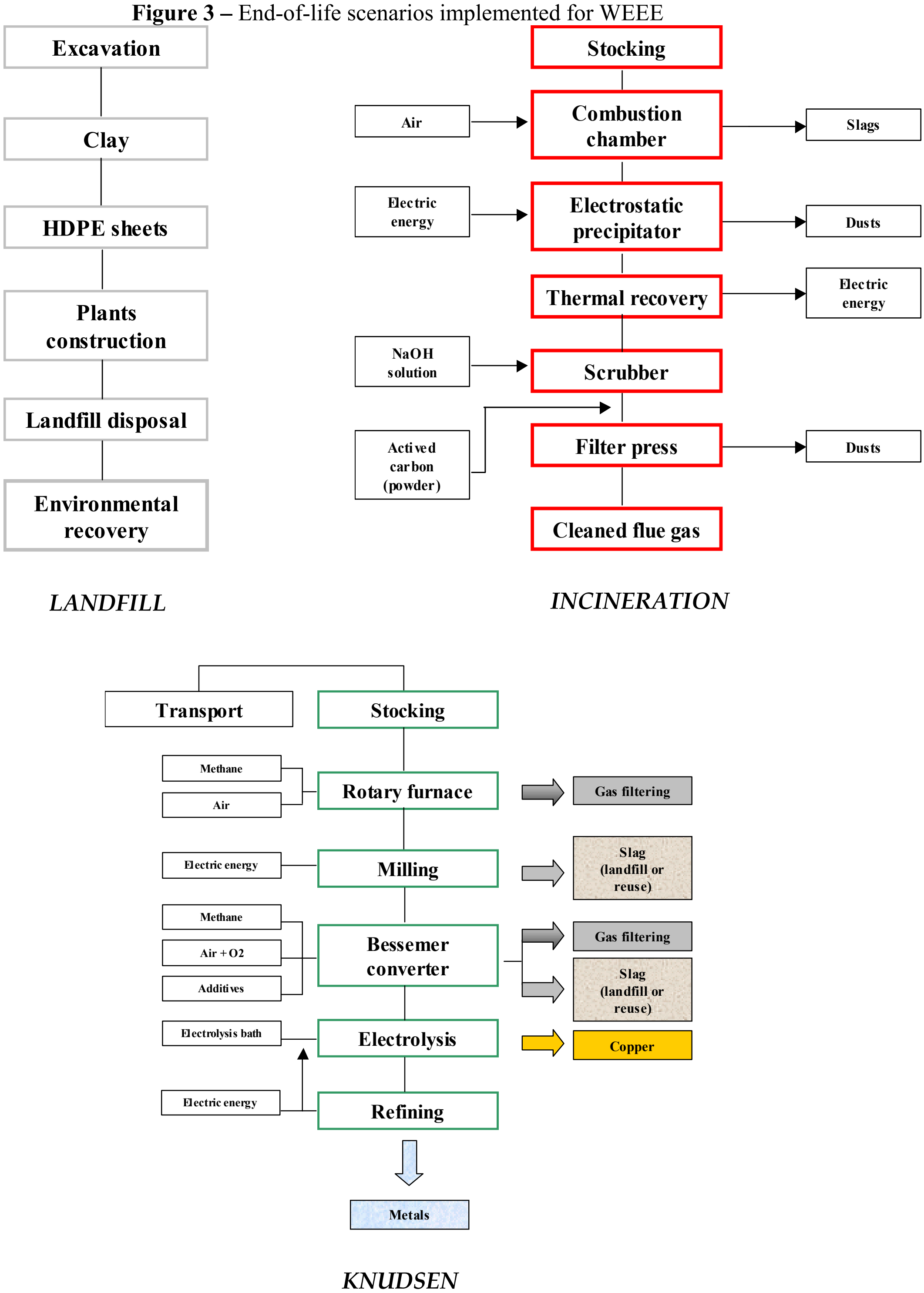
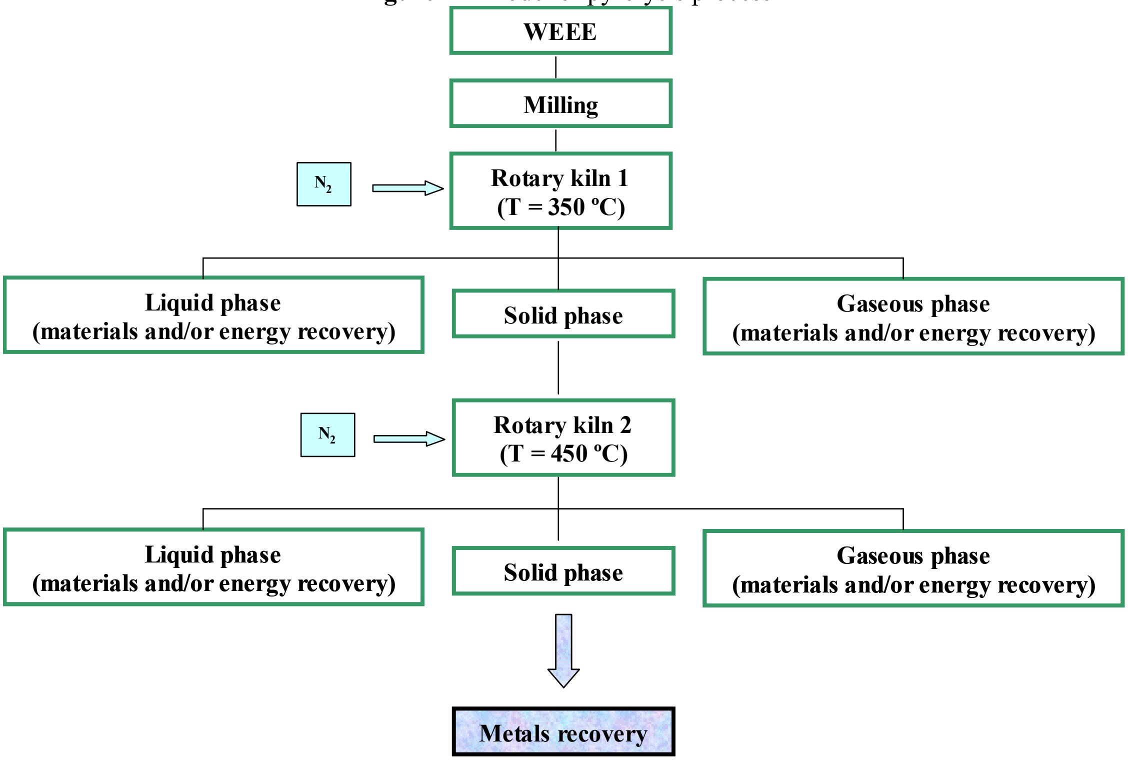


**Figure 4 –** Model of pyrolysis process




The information and data for the systems come from previous experiences and have been elaborated by means of the Boustead Model (version 4.4). About pyrolysis, the Inventory activity is still going on and results are still not available. In detail, data collection refers to Haloclean pilot plant that is performing in the context of the European Growth Project G1RD-CT-2002-03014.
Figure 5 shows the gross energy data associated with 1 kg of treted waste for the three scenarios (landfill, incineration and Knudsen processes):

1) feedstock energy is the starting credit of energy coming from plastics;
2) the energy consumption of each process is calculated taking into account the life-cycle of each plant and indicated as irreparably lost energy;
3) recovered energy is the energy produced by the process;
4) avoided environmental loads is the energy associated with the production of materials or energy recovered by the process.

Table 1 shows the gross energy requirement (GER) calculated for the three processes as well as some other indicators such as global warming potential (GWP), acidification potential (AP) and photochemical ozone creation potential (POCP).

**Figure 5 –** Gross energy data associated to 1 kg of treated WEEE for the three scenarios

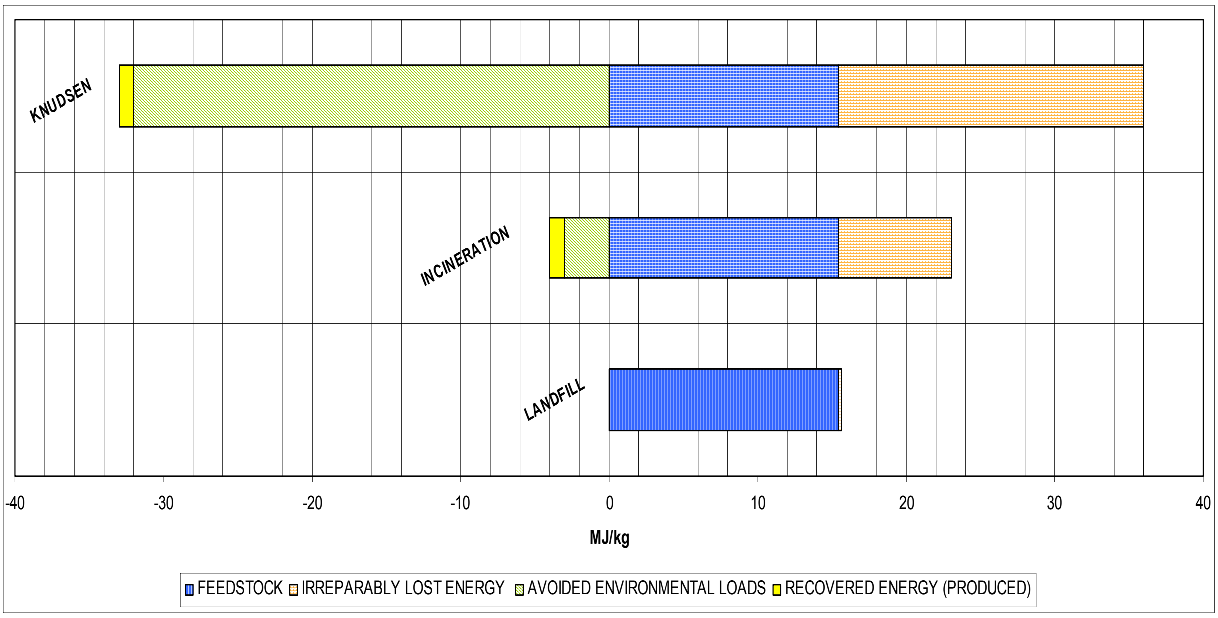



**Table 1. Some LCA indicators for landfill, incineration and Knudsen process**

| | **GER** | **$GWP_{100}$ [kg $CO_2$ – eq]** | **AP [g $SO_2$ – eq]** | **POCP [g $C_2H_4$ – eq]** |
|---|---|---|---|---|
| **Landfill** | 15,68 | - | - | - |
| **Incineration** | 19 | 1,53 | 8,9 | 3,3 |
| **Knudsen** | 4 | 5,4 | 60 | 3 |

## DISCUSSION

Even if a comparison between the four end-of-life scenarios here considered is not yet available because of the running of pyrolysis process Inventory analysis, some environmental considerations can be done.

Remarketing and reuse of WEEE is a good solution: recently, many enterprises in the EU are investing in this sector, with particular regard to eco-design activities.

Landfill disposal presents a low energy load: the gross energy requirement is almost made up of feedstock that is an irreparably lost energy. From the environmental point of view, it is important to remark that brominated compounds and heavy metals may concentrate in the lechate and that landfill disposal is linked to a natural resource depletion, the availability of territory. Moreover, such scenario does not fit the standards of the EU Directive.

Incineration presents an intermediate energetic load and it allows energy feedstock recovery through electric or thermal energy production, with a waste volume reduction of about 80-90%. From an environmental viewpoint, combustion of WEEE may be dangerous due to bromine, chlorine and heavy metals content. Moreover, incineration entails the definitive lost of recycling materials, in contrast with the aims of the EU Directive.

Knudsen recycling process presents high environmental impacts but a low energy load: although smelt and electrolytic phases are associated to high energy consumptions, this technology permits the recovery of feedstock energy of WEEE, through thermal energy production and of precious and strategic metals. It is estimated that is possible to recover the 95% of the economic value of electronic wastes.

Finally, pyrolysis process is one of the most attractive technique for WEEE recycling, due to the fact that gas fraction should be suitable for HBr production, the oils for chemicals recovery or fuel production and the solid residue for precious and strategic materials recovery. Since LCA activities started with primary data collection on the different technological step of the processes, the information about pyrolysis treatment are not still complete.

## REFERENCES


- AA.VV. - *International Journal of Life Cycle Assessment* - Ecomed Publishers, Germany, all volumes; http://www.scientificjournals.com/sj/lca/index.php
- Boustead I., Hancock G. (1979) - *Handbook of Industrial Energy Analysis* - The Open University, West Sussex, England.
- Legarth J., Alting L., Erichsen H., Gregersen J., Jorgensen J. (1994) – *Development of Environmental Guidelines for Electronic Appliances* – The Danish Technical University, Lyngby, Denmark.
- M.P. Luda, N. Euringer, U. Moratti (2003) – *WEEE recycling: pyrolysis of fire retardant model polymers* – Dipartimento di chimica IFM, Università di Torino, Italia.