ECO-COMPATIBILITY EVALUATION OF WEEE TREATMENT TECHNOLOGIES

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KEY WORDS: WEEE, pyrolysis, LCA

ABSTRACT

The Life Cycle Assessment (LCA) is a convenient tool to supply management strategies with particular attention to the choice between alternative processes [1] [2]. In this work, it has been applied to waste electrical and electronic equipment (WEEE) recycling by means of pyrolysis process. The comparison of this innovative technology is made with the conventional incineration and landfill scenarios.

INTRODUCTION

The management of WEEE is critical due to the high content of harmful substances, such us heavy metals and flame retardants. For these reasons, the EU WEEE directive (Waste Electrical and Electronic Equipment – 2002/96/EC) and ROHS (Restriction of Hazardous Substances – 2002/95/CE) have the aim, as first priority, of improving the environmental performance of all operations involved in the life cycle management of these equipments.

Following these main lines, the objective of the work is to present a LCA comparison between the actual end-of-life scenarios, incineration and landfill, and an innovative recycling technology, the pyrolysis.

METODOLOGICAL APPROACH

In detail, the analysis is focused on a specific EE waste, the CPU – Central Process Unit, with the aim to quantify the benefits of recycling activities. In particular, Figure 1 and 2 show a schematic overview of the system boundaries adopted for the processes under study [3].

Concerning landfill, data have been obtained from the I-LCA - the Italian LCA Data Base - and implemented in the Boustead Model v.5. The calorific value of 1 kg of CPU has been assumed equal to 13,53 MJ (energy lost and therefore accounted for energy consumption).

Also in the case of incineration, the information comes from the I-LCA Data Base and have been processed by the Boustead Model. The main hypotheses associated to such model are as follows:

- the energy recovery of the incineration plant, under the form of electric energy, is equal to 24.5%;
- the forecasted concentrations from the existing regulations in Italy, regarding atmospheric emissions, have been used;
- the use of NH_3, CaO and activated carbon for the treatment of emissions has been adopted;
- the capital energy related to the facility production has been considered, estimating the quantity of materials used (steel and cement). For the calculation, a medium life of the facility has been adopted equal to 15 years.

Finally, primary data about pyrolysis process come from the analysis carried out in the context of Haloclean European Project, Contract N* C1RD-CT-1999-00082 (“*Process integrated thermal treatment of halogens containing materials as source for halogens free fuels for steel production and residues for noble metals recovery*”) and refer to a pilot plant with a treatment capacity of 40 kg/h [4].

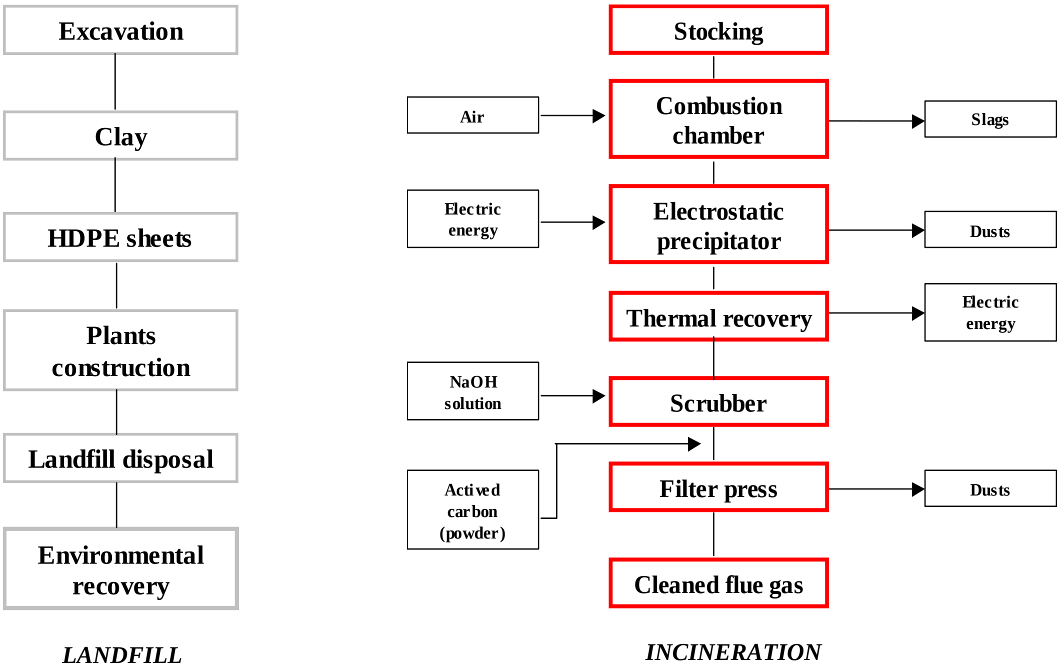

Figure 1 – System boundaries of standard end-of-life scenarios

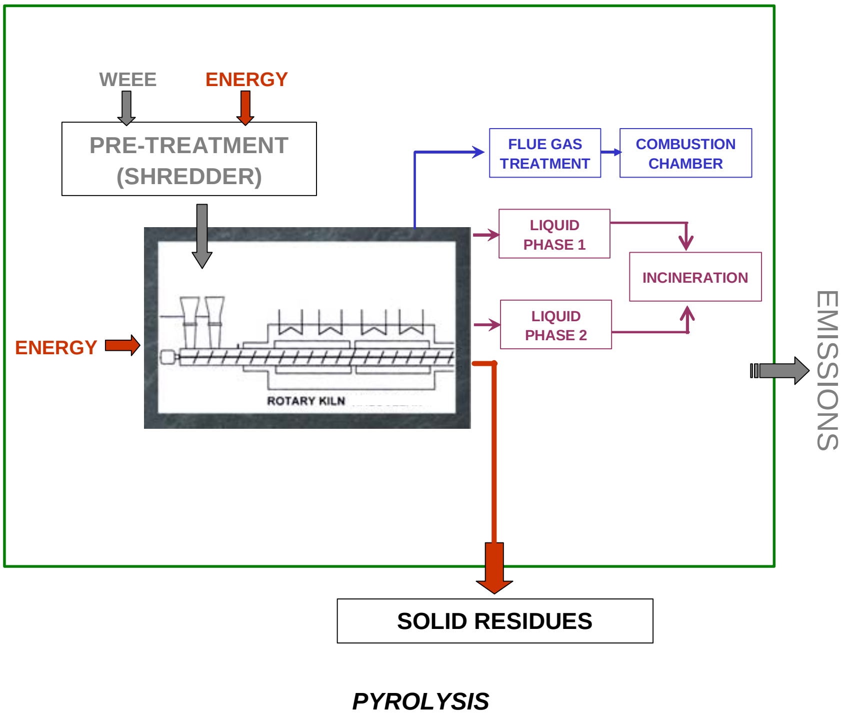

Figure 2 – Simplified system boundaries of the innovative pyrolysis system

As shown in the figures, the functional unit of the systems analysed is 1 kg of treated wastes (1 kg-input). In all the cases, the results refer to the Italian energy mix.

RESULTS

The results of the LCA are commonly splitted into the two following categories: **energy results**, represented by GER - *Gross Energy Requirements* indicator (Figure 3) and **environmental results**, concerning natural resources consumption, air emissions, water emissions and solid waste production for each functional unit.

In this paper, the environmental results will be not explicitly reported; however, according to ISO 14042, they will be converted into environmental indicators by means of several standardised mandatory elements. For this analysis, the following impact categories are considered: Greenhouse effect (GWP_{100} - Global Warming Potential) expressed as kg CO_2-eq./FU, Acidification (AP - Acidification Potential) expressed as mol H^+-eq./FU, Eutrophication (EP - Eutrophication Potential) expressed as g O_2-eq./FU and Photosmog (POCP – Photochemical Ozone Creation Potential) expressed as g C_2H_4-eq./FU (see figures 4, 5, 6 and 7).

It has to be underlined that, in the case of recycling, the environmental indicators have been calculated with two different methodologies: “Pyrolysis” results do not take into account the avoided impact (energy and materials recovery) while “Pyrolysis*” results include the avoided impact. Of course, the most convenient comparison has to be established with the “Pyrolysis*” approach.

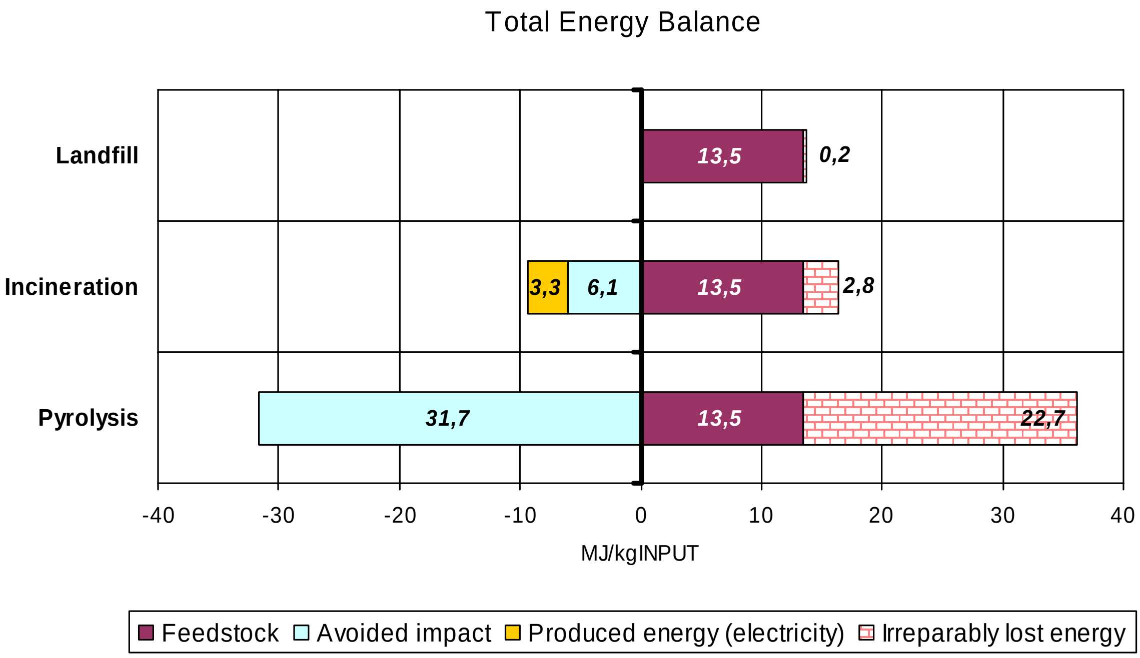

Figure 3 – The different contributes to GER for the end-of-life scenarios considered

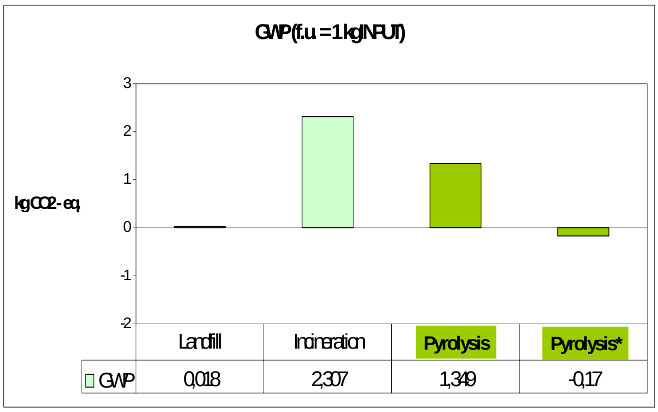

Figure 4 – Comparison of the GWP indicators

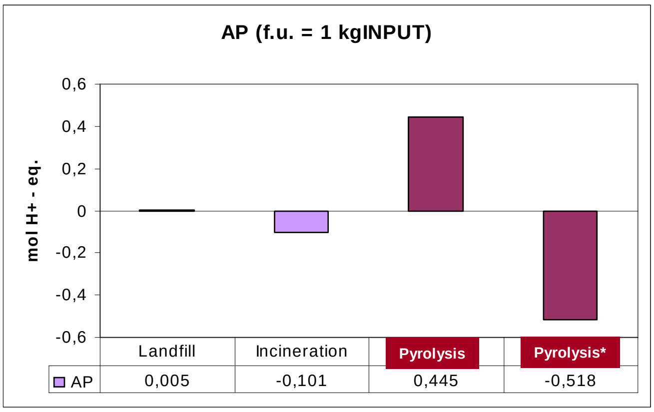

Figure 5 – Comparison of the AP indicators

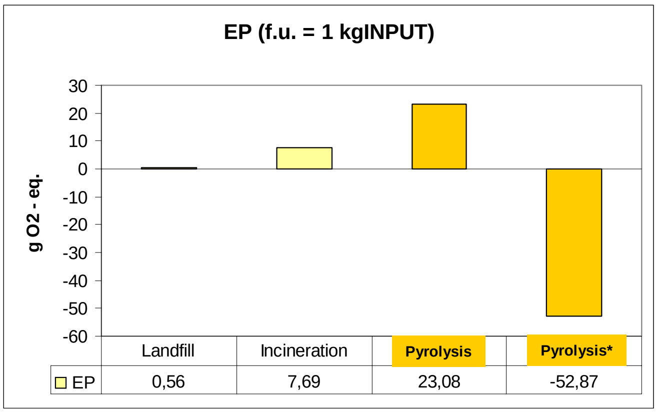

Figure 6 – Comparison of the EP indicators

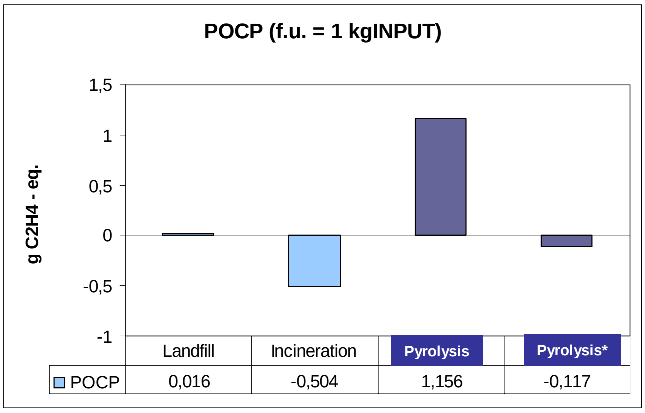

Figure 7 – Comparison of the POCP indicators

Due to the high electricity consumption, the pyrolysis recycling process presents the highest direct energy impact (about 22,7 MJ/kg$_{waste}$) if compared with the other end-of-life management strategies.

On the other hand, the significant contribution of the avoided impacts strongly underlines the importance of recycling: starting from a medium feedstock energy of 13,5 MJ/kg$_{waste}$, with an energy consumption of 22,7 MJ/kg$_{waste}$ (direct GER used for recycling process), it is possible to recover nearly 31,7 MJ/kg$_{waste}$ as noble metals, strategic metals and non-conventional fuels.

The positive effects linked to the materials and feedstock recovery are also clear as far as the global environmental indicators are concerned: if compared with landfill and incineration, pyrolysis shows the lowest GWP, AP and EP values. Only in the case of POCP, incineration shows a better performance.

CONCLUSIONS

The obtained results show that the CPU wastes (the WEEE with the maximum content of noble metals) have the best end-of-life scenario in the pyrolysis process. As the content of noble metals in the WEEE lowers, the advantages of this treatment decrease.

On the other hand, incineration is more favourable than landfill if the organic fraction in the waste is significant. This hypothesis is usually followed by the actual WEEE.

Finally, the pyrolysis is a very promising technique for WEEE recycling, due to the fact that the gas fraction could be easily treated and burned, the oils could be suitable for fuel production and/or chemicals recovery and the solid residues for precious and strategic materials recovery. Nevertheless, for the scale-up of the studied pilot plant, many efforts have to be done to characterise pyrolysis residues using different WEEE batch, with particular attention to liquid phase decontamination in case of post-use.

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