Life-Cycle Assessment of joint technologies for WEEE-cycle closure

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Introduction

Increasing demand for electrical and electronic equipment results in the generation of a rapidly growing waste stream worldwide, known by the acronym WEEE (Waste Electrical and Electronic Equipment) (Kuehr, 2019). The largest percentage is represented by dishwashers, washing machines, ovens, hobs and electric stoves which, in the Italian context, represent the 'Great Whites' and fall into the R2 grouping (WEEE Coordination Centre, 2024). These wastes consist of ferrous and non-ferrous metals (e.g., copper and aluminium), plastics, glass, precious materials and rare earths which need to be properly treated and recovered.

This study aims to assess the environmental sustainability (by means of life cycle analysis, LCA) of the recovery process of WEEE R2. For this purpose, a treatment plant located in Southern Italy was considered and the environmental impacts resulting from the current treatment scheme (Scenario 0) was assessed. Also, an advanced layout of the plant based on innovative technologies (Scenario 1) was analysed. The aim of this study was to perform a life cycle assessment of two different recovery options for R2 WEEE, with the aim of identifying the most environmentally sustainable alternative.

Materials and methods

The functional unit for the study was defined as 1 ton of WEEE belonging to the Italian grouping R2. The following scenarios were assumed:

- Scenario 0 represents the current process scheme of a WEEE R2 treatment plant in Southern Italy. The treatment operations consist of shredding the carcasses, manual sorting, grinding, magnetic separation of ferrous metals, eddy current separation of non-ferrous metals, and vibrating screen separating the remaining plastic material into three streams according to particle size. This scenario enables the End of Waste (EoW) of the ferrous fraction to be obtained; while, the other fractions (non-ferrous metals, plastics, steel) are destined to the recovery in third-party plants and the non-recoverable fractions (dust and scrap) to disposal in landfills.
- Scenario 1 represents a new management model for R2 WEEE, which from scenario 0 envisages the removal of the first manual separation step (post-shredding) and the implementation of innovative technologies: a vertical mill and a densimetric table to achieve the end of waste for copper and aluminium; a vertical mill, a tribo-loader and an electrostatic separator to treat the plastic fraction larger than 10 mm and obtain the end of waste of polypropylene (PP). In addition, the new model provides the pyrolysis of non-recyclable fractions.

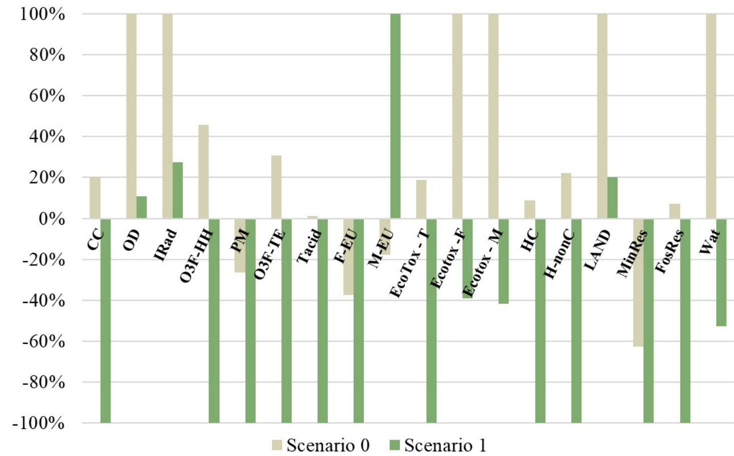
The life cycle assessment of the two R2 WEEE treatment scenarios was based on primary data from the plant under study, the scientific literature and the Ecoinvent 3 database. The Life Cycle Impact Assessment was performed using the calculation model SimaPro 9.5. according to ISO 140140:2006, with the Ecoinvent 3.10 database, at midpoint and endpoint level using the Recipe 2016 method in the Hierarchist perspective (Huijbregts et al., 2017).

Results

The midpoint comparison between the two scenarios shows how Scenario 1 is more advantageous than Scenario 0 (Figure 1). For both scenarios, the main contribution to environmental impacts related to *resource consumption* is attributable to electricity consumption (*MinRes, FosRes, Wat*).

As regards the *ecosystem impact categories*, the benefits associated with scenario 1 are maximum (e.g., Global warming). Scenario 1 is more impactful than scenario 0 for the Marine eutrophication category. This exception is related to the pyrolysis process that is absent in scenario 0, which, although leading to higher impacts, leads to higher benefits overall.

With regard to the categories related to the *effect on human health*, the impact values related to scenario 0 are maximum for categories Global warming, Ionising radiation and Water consumption; while, for scenario 1 maximum net benefits for categories Global warming, Human carcinogenic toxicity and Human non-carcinogenic toxicity.



CC = Global warming;
OD = Stratospheric ozone depletion;
IRad = Ionising radiation;
O3F-HH = Ozone formation, Human health;
PM = Fine particulate matter formation;
O3F-TE = Ozone formation, Terrestrial ecosystems;
PM= Terrestrial acidification;
F-EU = Freshwater eutrophication;
M-EU = Marine eutrophication;
EcoTox - T = Terrestrial ecotoxicity;
Ecotox -F = Freshwater ecotoxicity;
Ecotox – M = Marine ecotoxicity;
HC = Human carcinogenic toxicity;
H-nonC = Human non-carcinogenic toxicity;
LAND= Land use;
MinRes = Mineral resource scarcity;
FosRes = Fossil resource scarcity;
Wat = Water consumption

Figure 1. Midpoint characterisation

Despite some exceptions highlighted in the midpoint comparison related to the Marine Eutrophication category, the values for the different impact categories are mostly positive (impacts) for Scenario 0 and negative (benefits) for Scenario 1. This trend is confirmed by the endpoint comparison (Figure 2), which shows significant benefits regarding reduced impacts on human health, resource availability and ecosystem diversity for scenario 1.

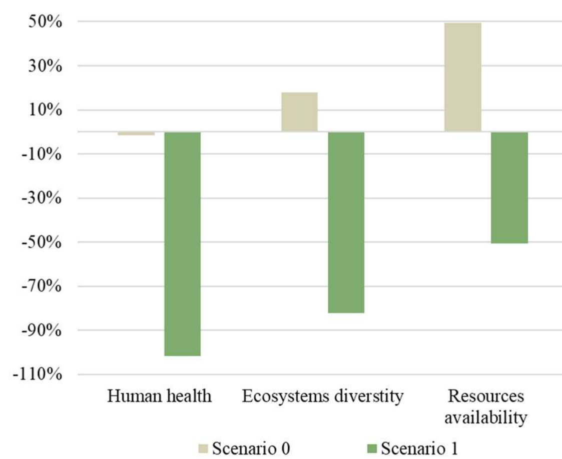


Figure 2 - Endpoint characterisation

Conclusions

Upgrading the plant layout by introducing innovative technologies, such as densimetric and tribo-electrostatic separation and pyrolysis, entails additional impacts for some categories. Still, overall, the benefits of producing secondary raw materials and energy recovery generate significant benefits that make it an environmentally preferable solution.

References

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