

Supplementary Materials

1. Definition section (ref: ILCD Handbook, 2011; ISO standards 14040-44, 2006)

Characterisation of elementary flows: To all classified elementary flows each one quantitative characterisation factor shall be assigned for each category to which the flow relevantly contributes ("characterisation"). That factor expresses how much that flow contributes to the impact category indicator (at midpoint level) or category endpoint indicator (at endpoint level).

Characterization factor: A factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator (e.g., to convert CH₄ to CO₂ equivalents for global warming potential).

Functional Unit: The quantitative definition of the system function for use as a reference unit, all inputs and outputs in the life cycle inventory and impact assessment are related to this unit.

Impact Assessment Method: A specific set of characterization factors.

Impact category: class representing environmental issues of concern to which life cycle inventory analysis results may be assigned. There are two main types of impact categories: midpoint and endpoint. The former allows to measure the environmental impact of the investigated system, at an intermediate point in the cause-effect chain. Examples are climate change, ozone depletion and water use. The endpoint categories refer to the macroareas of protection (final target), such as human health and ecosystem quality. Even though measuring impacts on endpoint categories offers a more comprehensive understanding of the environmental impact of the analyzed system, it is typically subject to greater uncertainty compared to the midpoint categories. The latter, in fact, being closer to the source of the impact are less affected by uncertainties and assumptions. Hence, midpoint impact categories are often used to compare different products or services.

Life Cycle Impact Assessment: The evaluation of the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product. The LCIA results (characterized impacts) are calculated by multiplying the individual inventory data of the LCI results with the characterisation factors.

Life Cycle Inventory: The compilation and quantification of material and energy inputs and outputs for a product throughout its life cycle.

System Boundaries: A set of criteria specifying which unit processes are part of a product system.

Safeguard subjects: The natural and human resources that are protected by environmental regulations and policies. These can include air, water, soil, biodiversity, human health, and cultural heritage.

Environmental damage: damages caused by resource consumption and pollutant emissions into the air, water, and soil.

Damage costs (or environmental costs): The financial costs associated with environmental damage, such as the cost of cleaning up pollution, repairing damage to ecosystems, and compensating people for health problems caused by environmental exposure. Negative values for damage costs indicate cost savings. This means that the analyzed process helps avoid more impactful processes, resulting in savings on impacts, associated damages, and repair expenses.

Externalities: The costs of economic activity that are borne by society as a whole, but not by the producers or consumers of the goods or services that generate those costs. Externalities can be positive (such as the benefits of clean air and water,) or negative (such as pollution and climate change). and are often not internalized by businesses, which means that they are not reflected in the prices of goods and services.

Internal costs: The costs of economic activity that are borne by the producers or consumers of the goods or services that generate those costs. Internal costs can include the cost of raw materials, labor, energy, and capital.

Life Cycle Costing (LCC): in an LCC analysis, the overall cost of a product or service over its entire life cycle, is assessed by considering internal costs, alone or together with externalities.

2. Sensitivity analysis

Composting

In this study, a compost yield of 50% w/w, as reported in the EcoInvent 3.8 database, and nutrient levels (N, K, P) for compost from generic biowaste [75], were considered. However, ISPRA [5] reported a compost yield of 27.3% for the composting plants located in the Campania Region, in 2019. Furthermore, according to Picca [99], by composting 1 ton of CS, an average of 17.7 kg of N (as N) and 13.5 kg of K (as K₂O) could be obtained, while the quantity of P would be zero or negligible [99]. The BaU Treatment environmental impacts, determined using the EcoInvent yield and the nutrient levels from [75], were compared with those obtained by employing either the ISPRA parameters or the Picca [99] parameters. Using the ISPRA compost yield, the average impacts increased by approximately 25%. Conversely, considering the nutrient levels indicated by Picca [99], savings of 4% were recorded (**Figure S1**).

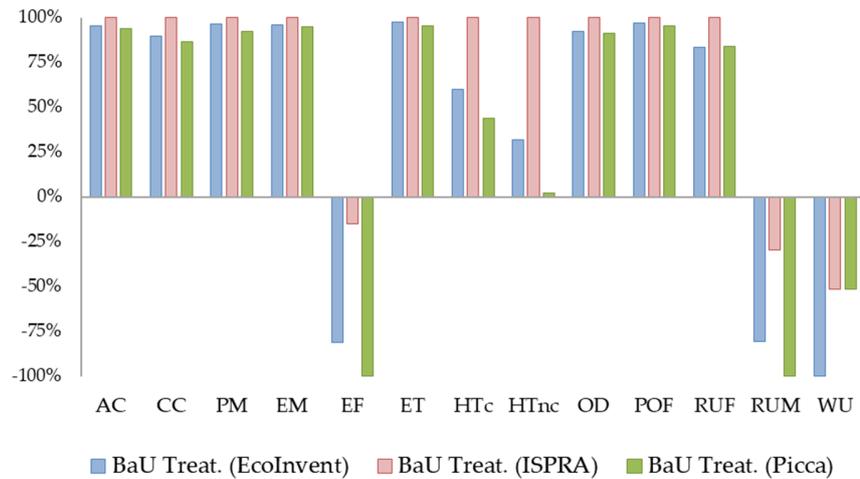


Figure S1. Comparison among the BaU Treatment impacts determined considering the compost yield and nutrient (N, K, P) content, according to: (i) EcoInvent v3.8 yield and the nutrient levels from [75]; (ii) ISPRA [5] yield; and (iii) Picca [99] nutrient contents.

Electricity

Since the consumption of electricity from the national electric grid (“Electric Mix”) was a major contributor to the observed environmental loads, a comparison with the use of electricity from 3 kW_p polycrystalline silicon photovoltaic (PV) panels (a renewable source), installed on the company roof [98], was performed. In particular, a focus was made on the Alternative scenario, since in its Pre-treatment and Treatment phases, electricity consumption accounted, averagely, for 67% and 81% of the total impacts, respectively. The comparison (**Figure S**) revealed that using photovoltaic energy (“PV”) allowed an average reduction, in the overall impact, of about 25%. In particular, the main benefits were the preservation of the ozone layer (OD impact category) and fossil resources (RUF), along with the reduction of greenhouse gas emissions (CC).

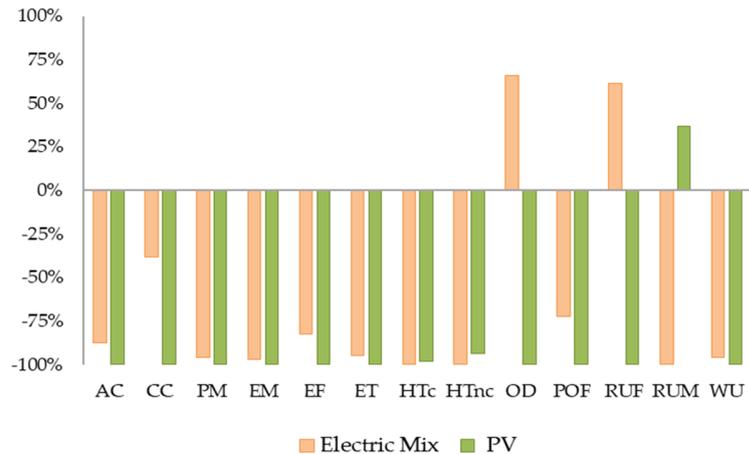


Figure S2. Comparison between the Alternative scenario characterized impacts associated with the use of electricity from: (i) the national electric grid (Electric Mix) and (ii) 3 kWp photovoltaic (PV) panels.

References

5. ISPRA. Rapporto Rifiuti Urbani—Edizione 2020; ISPRA-Istituto Superiore per la Protezione e la Ricerca Ambientale Via Vitaliano Brancati: Roma, Italy, 2020. Available online: isprambiente.gov.it/files2020/pubblicazioni/rapporti/rapportorifiutiurbani_ed-2020_n-331-1.pdf (Accessed on 18 October 2023).
75. Gilbert, J.; Siebert, S. ECN data REPORT 2022 Compost and digestate for a circular bioeconomy; European Compost Network ECN e.V: Bochum, Germany, 2022.
98. Gestore Servizi Energetici–GSE. Rapporto Statistico-Solare Fotovoltaico 2019. 2020. Available Online: https://www.gse.it/documenti_site/Documenti%20GSE/Rapporti%20statistici/Solare%20Fotovoltaico%20-%20Rapporto%20Statistico%202019.pdf (accessed on 23 October 2023).
99. Picca, G.; Plaza, C.; Madejón, E.; Panettieri, M. Compositing of Coffee Silverskin with Carbon Rich Materials Leads to High Quality Soil Amendments. *Waste Biomass Valorization* 2023, 14, 297–307. <https://doi.org/10.1007/s12649-022-01879-7>.