Summary

Solid Waste Management (SWM) is still a crucial issue for European countries, being strongly influenced by heterogeneous factors (i.e. social, political, technological, economic). The general objective of the present work is to use exergy criteria to assess the resource utilization into the Solid Waste (SW) treatment systems, including multiple scenarios and conflicting objectives. In order to include the systemic uncertainties, stochastic tools are adopted for generating simulation scenarios. The instruments of Exergoeconomics are used since exergy is considered a rational basis to compare flows of different nature (i.e. material and non-material). In a system-based analysis, a typical kerbside collection system is modelled and the influence of design and external variables on SW collection cost is evaluated. Then, an Exergoeconomic analysis of a Mechanical Biological Treatment (MBT) of unsorted Municipal Solid Waste (MSW), for Solid Recovered Fuel (SRF) production is performed. The primary sources or irreversibility are linked to material losses in the pre-screening phase (70% of the global input exergy). A crude Monte Carlo method is then used to sample from uniform distributions of degree of Selective Collection (SC) for single material stream, for reproducing the randomness in unsorted waste composition. The equipment energy consumption is considered as the internal uncertain variable. The results show the capacity of the system to dampen the fluctuations and confirm the primary influence of the external uncertain variables over the internal ones (RStD values about 90% lower). The analysis is then extended by including paper and plastic recycling chains. The concept of Embodied Exergy (EE) is used to account for the avoided or additional exergy in different scenarios of SC. In general, the system shows a good degree of self-regulation, even if savings in EE diminish for high SC, because of the influence of SW transport and alternative fuel supply cost. Three exergy-based indicators, i.e. the Global Exergy Efficiency (GEE), the Additional Exergy Indicator (AEI) and the Exergy Scenario Comparison (ESC), are developed for comparing different recycling scenarios according to the recycling rate of single material streams. Moreover, a Multi-Objective Functions (MOFs) Optimization between the GEE and the total monetary cost is performed for seeking the best trade-off solutions; the optimization variables are linked to the amount of recycled materials. In general, the values of

exergy-based indicators confirm the advantage of having recycling options for a better use of resources with respect with the no-treatment case (i.e. landfill disposal). The additional exergy investment for recovering the input waste internal chemical exergy amounts to about 3.21% for transport and 6.22% for recycling, expressed as a percentage of the total invested exergy. The output solutions from MOFs optimization show a series of trade-off points, even if higher monetary costs are associated to total recycling options. The paper recycling rate is the most influencing variable of the cost range of the optimal solutions. In a specific material-based view, exergy is also used for comparing the resources invested in producing polymers from primary material with those from secondary materials through recycling. The production routes of nine polymers (i.e. PE, PP, PVC, ABS, PU, PA6.6, PET, SBR, EPDM) are established according to the 'grave-to-cradle' path (including polymerization, oil derivatives production and fossil fuel extraction). The mechanical and chemical recycling indexes are developed depending on the final product (e.g. the new crude polymeric material or the oil derivatives). The comparison confirms the convenience of some already used practices and the benefit of recycling in terms of global resource utilization. Finally, a specific application for a thermodynamic assessment of End-of-Life vehicle plastic components is presented. Calculating the total EE of the vehicle plastic components gives an idea of the order of magnitude of the resources (expressed in MJ of exergy) that are definitively dispersed in case that the materials are not reused or recycled (i.e. landfill disposal or incineration).