EVALUATION OF THE ENVIRONMENTAL SUSTAINABILITY OF DIFFERENT WASTE-TO-ENERGY PLANT CONFIGURATIONS

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European strategy for waste management attributes primary importance to waste production prevention and imposes a priority order in waste management based on: "preparing for re-use; recycling; other recovery, e.g. energy recovery; and disposal" [1]. According to this strategy, those wastes for which the material recovery is not effectively applicable, should be used for energy recovery. Unsorted municipal residual waste (i.e. the waste left downstream of separate collection), has an average lower heating value higher than 10 GJ/Mg, in EU, and can be recovered in modern Waste-to-Energy (WtE) plants, producing combined heat and power (CHP) and reaching high levels of energy recovery. CHP is pinpointed as the best techniques for energy recovery from waste and also it is the technical solution that allows reaching high values according to the R1 criteria [1]. However, in some cases, heat recovery is not technically feasible – due to the absence of thermal user (industrial plant or district heating) in the proximity of the WtE plant - and only power production remains as the unique possibility. In these cases, some challenges are posed in order to increase as much as possible the energy performances: high values are obtainable only for large WtE plants [2-3]. High energy recovery efficiency values are very important, not only to comply with the R1 criteria, but also for the environmental sustainability of WtE plants. The highest the electricity and heat produced, the best saving of natural resources may be achieved. Pavlas et al. [3] evaluated the benefits of energy recovery in WtE by CHP applying a method based on Primary Energy Saving (PES). Damgaard et al. [4] showed that CHP is able provide higher saving, in Life Cycle Assessment (LCA) evaluations, than only electricity recovery. Within this frame, the aim of this work is to carry out an environmental assessment, through LCA, of different configurations of municipal residual waste WtE plant, i.e. only power production vs. increasing degree of cogeneration. The size ranging from small to large plants (12.5-300 MW thermal power input) was considered, including gradually the technical improvements that may increase the overall plant performances. Additionally, some specific configurations, related to energy recovery integration into the flue gas treatment (FGT) system, considering acid gas removal dry processes using calcium or sodium-based reactants, were investigated. The WtE process was simulated by a home developed thermodynamic model (using Engineering Equation Solver, F-Chart Software), providing the material and energy streams in input and output to/from the process, allowing the R1 calculation. LCA system boundary also included municipal residual waste transportation to WtE, production processes of input chemicals, bottom ash transport, treatment and recovery, fly ash and air pollution residues transport, treatment and disposal and, obviously, avoided effects of conventional heat and power production. Impact assessment results were calculated using cumulative energy demand (CED) and ReCiPe 2008 methods, even if here we discuss only climate change indicator results. Regarding only power production mode, the improved net electric efficiency along with the size allows for increasing the R1 value and decreasing the CO_2 equivalent emissions. However, only medium-large plants (larger than 50 MW) reach R1 values higher than 0,65 and only 200-300 MW size plants reach negative CO_2 equivalent emissions, even without cogeneration. Smaller plants need to operate in cogeneration mode – according to different extents - to reach imposed R1 value and to obtain negative CO_2 equivalent emissions. As a matter of fact, a plant able to comply with the R1 limit, not always shows neutral carbon balance. Thus, in order to make WtE processes acting as carbon sink, cogeneration should be employed in larger extent than the minimum required for R1 compliance. Some specific configurations, related to energy recovery integration into the FGT system allow enhancing energy efficiency: a FGT line with injection of sodium bicarbonate at 180° C and a tail-end heat recovery used for pre-heating primary combustion air has a positive influence on R1 value and CO_2 balance.

References

[1] Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives - Annex II, 19 November 2008.

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[4]Damgaard, A., Riber, C., Fruergaard, T., Hulgaard, T., Christensen, T.H., 2010. Life-cycle-assessment of the historical development of air pollution control and energy recovery in waste incineration. Waste Manage, 30, 1244–1250.