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Sustainable waste management: Waste to energy plant as an alternative to landfill

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ABSTRACT

The management of municipal solid waste (MSW) has been identified as one of the global challenges that must be carefully faced in order to achieve sustainability goals. European Union (EU) has defined as Waste to Energy (WTE) technology is able to create synergies with EU energy and climate policy, without compromising the achievement of higher reuse and recycling rates. The methodology used in this paper is based on two levels. A strategy analysis defines the amount of waste to incinerate with energy recovery considering different approaches based on unsorted waste, landfilled waste and separated collection rate, respectively. Consequently, it is evaluated the sustainability of a WTE plant as an alternative to landfill for a specific area. Two indicators are used: the Reduction of the Emissions of equivalent Carbon Dioxide (ER_{CO2eq}) and Financial Net Present Value (FNPV). Furthermore, a social analysis is conducted through interviews to identify the most critical elements determining the aversion toward the WTE realization.

The obtained results show the opportunity to realize a 150 kt plant in the only electrical configuration. In fact, the cogenerative configuration reaches better environmental performances, but it is not profitable for this size. Profits are equal to 25.4 € per kiloton of treated waste and 370 $kgCO_2eq$ per ton of treated waste are avoided using a WTE plant as an alternative to landfill. In this way, the percentage of energy recovery ranges from 21% to 25% in examined scenarios and disposal waste is minimised in order to preserve resources for the future.

1. Introduction

Sustainability is a cross-disciplinary topic that is analysed by researchers, policy makers and community members. Protection of people and the environment and conservation of resources are the goals of waste management [1–3]. In the context of sustainable waste management (SWM), sustainability is defined the assessment of environmental, economic, and social impacts of available waste treatment options [4]. SWM is tangible when the generation of waste and harmful substances is minimised, the reused (using materials repeatedly), recycled (using materials to make new products) or recovered (producing energy from waste) materials are maximised, and disposal waste is minimised in order to preserve resources for the future [5–7].

The European Commission adopted a Circular Economy Package, in which the proposed actions can contribute to closing loop of product lifecycles [8]. Several works have defined that the materials in informal waste dumps or in structured landfills is the opposite of a closed loop system [9,10]. The opportunity to valorise, as materials (Waste to Product (WTP)) and/or as energy (WTE), certain waste streams is strategic for public health and environmental protection [11,12].

Several methods have been proposed to evaluate SWM, e.g. exergy analysis, life cycle assessment (LCA), exergetic life cycle assessment (ELCA), analytical hierarchical process (AHP), life cycle costing (LCC) and discounted cash flow (DCF) [13,14]. Many works have reviewed the sustainability of WTE technologies. They defined it as an opportunity for a sustainable production of energy [15], giving a contribution for supplying renewable energy [16] and for tackling climate change [17]. Consequently, WTE plant provides a method of simultaneously addressing the problems of energy demand, waste management and greenhouse (GHG) emissions [18].

Energy, economic and environmental (3E) impacts of WTE for MSW management are evaluated by [19], considering several WTE technologies including the landfill gas recovery system, incineration, anaerobic digestion (AD) and gasification. The 3E results indicate incineration as the best solution, when combined heat and power (CHP) is considered. Instead, AD is more favourable, when only electricity is produced. Other comparisons are proposed in literature: e.g. WTE present the best performing technology in

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comparison to mechanical biological treatment (anaerobic and aerobic) in according to environmental, economic and social criteria [20] and WTE plants present economic and financial benefits, new employment opportunities and the reduction of GHG emissions as alternative to landfill use [21].

The literature review reveals that a work that analyses together environmental, economic, and social impacts of WTE plant in a specific area as an alternative to landfill use is absent in literature. This paper attempts to fill this gap by evaluating the sustainability of this technology. A case study of an Italian region (called Abruzzo) is conducted. A strategic analysis is proposed as the initial step of a decision-making process. It defines the amount of waste to send to incineration based on energy recovery. Three different approaches based on unsorted waste, landfilled waste and separated collection rate are used to define the amount of recovered waste and furthermore, two kinds of energy recovery (CHP and only electrical configuration) are analysed to evaluate environmental and economic performances.

The remainder paper is organized as follows: initially, the literature preview is described in Section 2 and data and methods of waste management in Europe and Italy are presented in Section 3. Subsequently, methodology and input data are illustrated in Section 4. Obtained results are subdivided into two parts: a strategy analysis is presented in Section 5 and financial, environmental and social assessments are proposed in Section 6. Conclusions and some general considerations are presented in Section 7.

2. Literature review

The EU waste hierarchy Directive 2008/98/EC defines the priorities in waste management: it gives preference to waste prevention and minimization, then to reuse and recycling, then to energy recovery and finally to disposal (landfill) – Fig. 1.

A WTE technology is a treatment process of recovering energy in a form of heat, electricity or transport fuels from a waste source [23]. Mass-burn incineration (MBI) is the most commonly used WTE technology. This type of incineration includes large-scale combustion of waste in a single-stage chamber unit where complete combustion or oxidation occurs, characterized by high operating temperatures [26]. The last generation of WTE plant is characterized by an improvement concerning the performance of the chemical conversion process, but also by advanced technologies for pollution control systems [24]. Consequently, today it can be seen as efficient industrial unit for destroying hazardous organic substances, recovering energy and materials, and saving landfill space [25].

Non-combustible materials, e.g. glass, metals, inert waste and the organic fraction of waste (e.g. food waste, agricultural) are basically eliminated before proceeding to incineration [27]. It treated several types of waste such as solid, liquid (e.g. domestic sewage) and gaseous (e.g. refinery gases). However, municipal solid waste (MSW) represents the most common application [28]. Six categories of MSW are examined by [29]. This work has shown that the best practice is to recycle paper, wood, and plastics, to anaerobically digest food and yard waste, and to incinerate textile.

Environmental impacts of MSW management have been studied extensively, including a number of LCA studies [30]. The disposal of waste in landfills presents serious and dangerous effects on the ecosystem [31] and incineration with energy recovery achieved better environmental performances than recovery of biogas from landfill across all impact categories, except for human toxicity [32]. Environmental improvements concerning the combustion WTE unit can be achieved sending a larger percentage of bottom ashes to an up-to-date process for recovery of materials [33]. WTE plants are able to destroy completely hazardous organic materials, to reduce risks due to pathogenic microorganisms and viruses and to concentrate valuable as well as toxic metals in certain fractions [34]. A comparison between two kinds of energy recovery is proposed by [35]: the environmental convenience corresponds to the cogenerative configuration, while the economic advantages are linked to the only electrical one.

Some successful aspects of applying WTE techniques are: (i) green fuel pellets utilized for heating supply; (ii) paper and pulping industry wastes utilized for CHP plant; (iii) animal residues utilized for biogas production and (iv) MSW/wastewater treatment plant utilized as a district energy supply centre [18]. Furthermore, the presence of a low share of biowaste in mixed MSW decreases the moisture content of the waste, increasing the heating value. Besides of this, authors have highlighted as a high share of plastic increases the heating value and the non-renewable share of energy in the waste material. Also, an high presence of paper and cardboard produce the same effect, although they are characterized by a lower heating value [36].

WTE can play a key-role in SWM, without compromising the achievement of higher reuse and recycling rates [37]. In fact, this technology is able to create synergies with EU energy and climate policy [38] guided by the principles of the EU waste hierarchy [8].

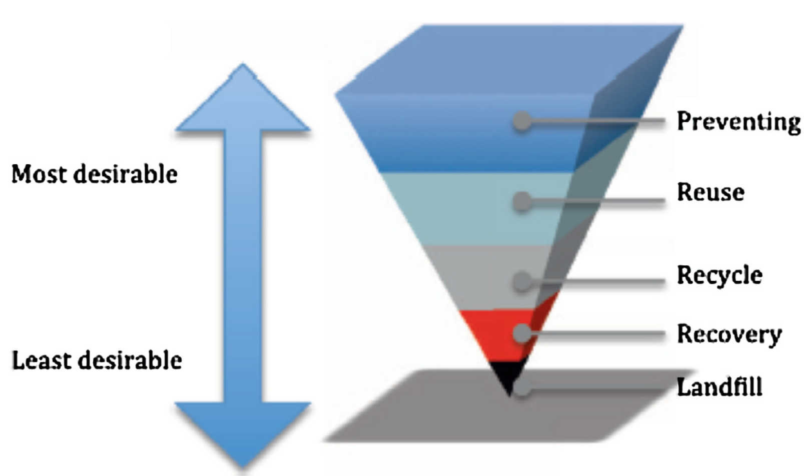

Fig. 1. Waste management hierarchy [22].