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Utilization of energy from waste potential in Turkey as distributed secondary renewable energy source

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ABSTRACT

Running out of fossil fuels and rising of environmental issues pressurize energy policies in the direction of increasing renewable energy utilization. As a part of full-recycling scheme, Municipal Solid Waste (MSW) can be accounted as an alternative and prevalent source of renewable energy for smart grid applications. This study presents a case study investigating the future of dry combustion in Turkey and gives some projections on Energy from Waste (EfW) utilization potentials as secondary local generators. EfW potential of MSW incineration plants is modeled depending on MSW mass function. An empirical formula for prediction of EfW potential of Turkey is derived by curve fitting to yearly MSW data. Dependence of EfW potential on human population is modeled and thus spread of EfW potential over the territory of Anatolia landscape is illustrated. Analyses reveal that EfW has a potential to be local source of renewable energy for future smart grids due to the fact that EfW exhibits energy generation distribution correlated with city population. We concluded that EfW incineration plants can act on sustainable development of Turkey by serving as a consistent, distributed, near-field generators integrated to waste management systems of cities.

1. Introduction

Waste should not be considered as "anything rejected as worthless, or in excess of what is required" [1]. Bailie et al. gave more relevant meaning for the waste term as "any material that enters the waste-management system", for recycling, reuse, material reclamation, composting and incineration [2]. The last definition is more pertinent for a sustainable development of civilizations. Because, if waste disposal systems are not improved to manage full recycling of waste materials, natural resources will be insufficient to meet demands of increasing population, and the human race, sooner or later, faces contamination and insufficiency of natural resources. The best solution for a sustainable world is to implement full-recycling schemes. One of the promising benefits of the waste management is also reuse of waste material for energy harvesting. It is anticipated that "waste to energy" conversion may help to get rid of problems of electricity scarcity and waste management together. The full-recycling paradigm can be possible by recovery of the both energy consumed and materials used in the manufacturing.

Fig. 1 illustrates a conceptual diagram of full-recycling paradigm. Full-recycling paradigm suggests a complete reuse of compounds and energy contained by the materials so that sustainable working of a system can be possible. This makes systems entirely self-supportive and renewable in a closed loop manner. For industry, full-recycling scheme also makes possible the zero-carbon manufacturing [3]. Full-recycling scheme should be a mandatory for sustainable development and eco-friendly living in the earth. Otherwise, contamination of environment due to the human activity is unavoidable.

A habitable world in future depends on our capacity to use natural resources in a way of eco-friendly and efficient. In this point, increasing the recycling and renewable energy utilization are two key-points, which must be always taken into account when designing social, economical and manufacturing systems in the global scale. EfW policies should be an essential part of landfill diversion and climate change strategies [4].

MSWs collected from urban areas should be disposed in way of resulting in minimal environmental impacts. This objective can be achievable by following full-recycling scheme that aims a complete reuse of not only materials but also energy contained by the MSWs. In this sense, EfW is recognized as renewable energy generated

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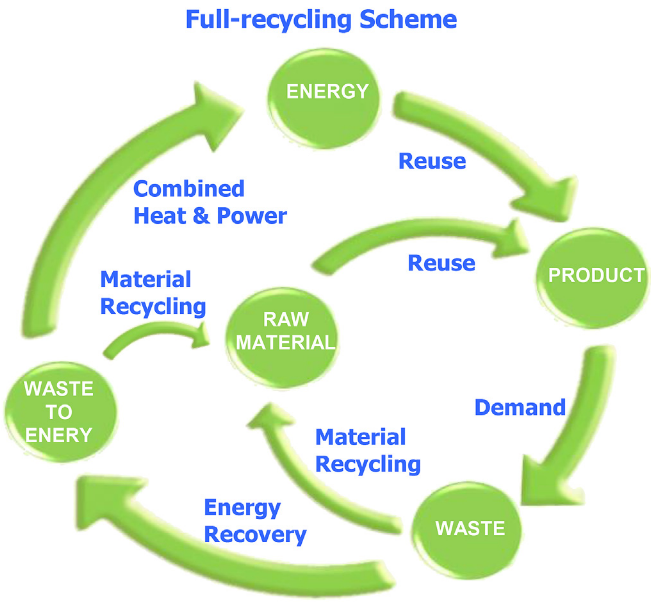

Fig. 1. An illustration of full-recycling scheme.

from waste management system [5]. Integration of EfW systems to electricity grid will be very beneficial when they are considered as distributed sources assembled to waste disposal systems of provinces. This integration becomes a major step toward the realization of full-recycling paradigm.

Waste disposal by waste incineration in open fields and/or buried for landfill contains the risk of emissions of toxic contaminants and heavy metals to nature [6]. After waste separation for material recycling (paper, glass, metals..etc), fully burning of non-recyclable and contaminant material under high temperature combustion rooms integrated with effective fabric, ash and gas filters (gas cleaning techniques) can reduce contamination risks caused from waste disposal process, noticeably [6]. Today, heat energy emerged from combustion of waste material can be used for electricity generation via heat to electricity generation techniques. Modern waste combustion plants are more efficient in energy generation and material disposal, which can reduce the volume of the original waste by 95–96%, depending upon composition of materials. Application of advanced material filters and combined heat and power (CHP) methods [7,8] makes EfW more efficient and eco-friendly in term of energy generation. State-of-the-art EfW incinerators, practicable recycling and composting process are suggested to work together in an integrated waste management strategy [9]. EfW incineration is suggested as an integral part of environmentally responsible and sustainable waste management strategy [3,10,11]. There are efforts for the strategic municipal solid waste management in regional scales [12].

Future smart grid technologies aim the realization of distributed generation, distributed storage and demand side load management for energy systems [13–16]. Thus, local distributed renewable generation and electricity demand elasticity can be possible by implementation of smart grid technologies, which in turn enhance energy efficiency and sustainability in generation, distribution and consumption. Authors suggest that EfW systems should be accounted as distributed renewable energy generators for smart grids: The generation potential depends on MSW production of cities. Hence, it presents advantageous of more steady and predictable generation pattern comparing to generation profiles of other renewable energy sources such as solar or wind energies. Another advantage of EfW is that generation potential of EfW varies depending on population of the provinces. This well suits for local distributed generation provisions of smart grids. As a distributed resource, EfW presents benefits of generation consistency and suspension. These properties significantly facilitate management of renewable energy resources and make EfW a good candidate for smart grid distributed generation applications so that it becomes an easy-manageable and consistent source of renewable energy. EfW is also suitable for CHP applications that increase energy efficiency in generation systems. Environmental and economic advantages of EfW integration to city-wide district energy network was discussed in detail by Finney et al. [17].

This paper highlights that EfW promises a consistent distributed generation potential for future smart grids. Many previous works have been discussed methodologies developed for generation of electricity and/or heat energy from waste materials: The directly waste combustion, the bioconversion such as anaerobic digestion or fermentation producing methane or alcohol, and the landfilling producing a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels [18]. Assamoi et al. reported that waste disposal by incineration was more beneficial in term of environmental offset and electricity generation potential while landfilling is preferable financially [19]. Industrial waste such as plastics, leather and rubber reduce the energy potential of landfill. Whereas, increasing portion of plastics, leather and rubber wastes enhances the energy potential of the incineration method [19].

Numerous works associated with biomass [20–24] and biogass [25–27] addressed energy recovery from wastes or residual materials to be a solution for sustainable development in many countries. For environment and climate point of view, a complete system engineering study was presented by Söderman for the energy recovery from waste in Sweden [28]. Söderman suggested that a preferable solution considering global warming implications should combine materials recovery and CHP from waste materials [28]. In another study, Udomsri et al. gives an evaluation of MSW incineration for climate change mitigation and promotion of biomass-based electricity production in Thailand [20]. They reported that MSW incineration can lessen environmental impacts associated with waste disposal and thus contributes to expanding biomass-based energy production in Thailand [20].

Longden et al. discussed distributed or centralized energy-from-waste policies and suggested that decision of the right EfW strategies can be possible by assessment and analysis local parameters, social, financial and geographical conditions [4]. In literature, many studies are devoted to assessment and planning of EfW potentials in country scales such as Delhi [29], Saudi Arabia [30], Brazil [31,32], Jordan [33], Portugal [34]. All these case studies are very helpful for the establishment of right EfW policies for their countries. All these works motivate us to analyze current and future potential of EfW in Turkey and provide future projections for the roles of decentralized EfW in the prospective smart grid applications.

This paper presents a case study investigating EfW potential of Turkey and gives an estimation of EfW potential in Turkey for near future. Dependence of EfW potential to human population was modeled for Turkey. Moreover, we demonstrate spread of EfW potential over the territory of Anatolia landscape in a correlation with city population, and conclude that EfW incineration plants can serve as a consistent, distributed, near-field (local) generators around cities for the sustainable development of Turkey. Possible benefits of EfW generation for a future smart grid installation in Turkey are discussed, briefly.

2. Fundamentals of EfW by dry combustion technology

The combustion of solid organic materials is the most common EfW method, and particularly waste incineration combined with