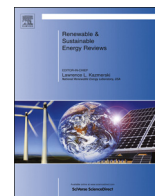




Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Waste-to-energy: An opportunity for a new industrial typology in Abu Dhabi

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ARTICLE INFO

Keywords:

Waste-to-energy
Industrial architecture
Recycling
Renewable energy
Abu Dhabi

ABSTRACT

Despite the current strides in recycling in both the USA and Europe the remaining amounts of waste that need to be disposed of keep on increasing. Reversal of this trend is extremely challenging, given the expected increase in global population, and as developing countries adapt consuming patterns resembling those of the USA and Europe. It appears then, given the multi-faceted disadvantages of landfilling, that thermal treatment will become the dominant disposal option for the foreseeable future.

The United Arab Emirates' production of municipal waste places it in the top five countries in the world, consistent with the strong correlation found to exist between waste generation and level of urbanization and gross domestic product of a country. The scarcity of water in the UAE and the proximity of its aquifers to the ground surface make it very questionable whether landfilling is appropriate for the country. Thus, recycling and incineration appear to be the only solid waste management options for UAE, and this country's response to its waste problem can be thought of, also, as a test of how an advanced, affluent society can address the problem of mounting waste.

Related to these is the size of the incineration facilities and the need, in many cases, to be located close or within the urban environment. This point is explored in this work in arguing that a re-invention of the industrial building in the context of a modern city is a necessity, and should be approached not on a case-by-case basis, but in a systematic fashion where incineration facilities become integral parts of the urban landscape. The city of Abu Dhabi, UAE with its iconic buildings and forward-looking approach to urban planning and building design serves here as a model city, where such an integration could take place.

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1. Introduction

Municipal solid waste (MSW) management alternatives are limited to landfilling, incineration, and recycling/reusing. The practice of landfilling in the majority of advanced countries is in a steady decline as a result of the potential for soil, water, and air contamination and the associated health risks, the lack of appropriate space near urban

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<http://dx.doi.org/10.1016/j.rser.2015.07.098>

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centers, and the deterioration of the neighboring-to-a-landfill urban environment [1–3].

The trend toward recycling/reusing and thermal treatment of the waste is evident both in the USA and the European Union (EU). Thus, in USA disposal of waste to landfills declined from 89% of the total MSW generated in 1980 to 53.8% in 2012. Recycling and composting, which accounted for less than 10% until 1980, increased to 34.5% in 2012. Treatment of the MSW with thermal methods reached 11.7% of the total waste stream in 2012 with about 300 waste-to-energy facilities operating in USA the same year. Per capita MSW generation in USA increased almost linearly from 1.22 kg per person per day in 1960 to a peak of 2.15 kg in 2000 and appears to have stabilized since then to about 2 kg per person per day. Despite this progress in recycling efforts, the increase in total MSW from 151.6 million tons in 1980 to 251 million tons in 2012 meant that whereas in 1980 an amount equal to 137.1 million tons had to be disposed of through landfilling or incineration, in 2012 this amount had risen to 164.3 million tons (all quantities are reported here in units of US tons, which correspond to 1.1023 metric tonnes) [4].

The quantity that needs to be disposed of in 2012, after recycling, is almost double of the total waste generated in USA in 1960 – when recycling was still in its infancy [4]. It is instrumental to note that the increase of the population, which was about 179 million in 1960 to the current 317 million people accounts only partially for the waste increase in USA. Keeping everything the same, i.e., if the US consuming and waste generation patterns of the 1960s remained the same during this period then, just the increase of the population would have resulted to 2.16 kg per person per day. Thus, it can be deduced that 0.94 kg per person per day was added to the 1960s waste solely due to the population increase in USA. Further, if one considers that the recycling rate increased from 6.4% in 1960 to 34.5% in 2012 this 2.16 kg per person per day should have been reduced to 1.55 kg per person per day as a result of the increased recycling efforts [4]. This differential of 0.45 kg per person per day from the current 2 kg per person per day, if the same population and recycling rate are considered, is the result of the changing lifestyle and the ensuing waste generation in USA. In other terms the true effect of recycling was to reduce the waste from 2.61 kg per person per day – taking as baseline the 1960s 1.22 kg per person per day plus 0.94 kg per person per day for the population increase plus 0.45 kg per person per day for the lifestyle waste generation expansion – to 2 kg per person per day. It appears then, that although recycling can mitigate to some degree the effect of modern lifestyle and the increase of the population focusing only on recycling is not sufficient, but a change in consuming and waste generation habits needs to be advanced in order to reverse the trend of the increased waste.

In the EU 27-member states the average per capita MSW generation stood at 1.3 kg per person per day in 1995 and appears to have stabilized to a little less than 1.4 kg per person per day during the decade of 1999–2009. More than two-thirds of the EU countries increased the amount of waste they produced during 2001–2010, and for those few that decreased their waste this reduction was not substantial and may have been attributed to the declining economic conditions in Europe [6]. There exist significant variations in MSW production among the EU-member states that range from 0.75 kg per person per day in Romania to about 2 kg per person per day in Denmark. These are due to variable consumption patterns, management practices, and economic wealth of a member state [5]. In EU-27 the creation of MSW rose from a total of 204 million tons in 1995 to 219.5 million tons in 2013. Despite this increase landfilling declined from a 64% share of the total waste stream to about 30% share in 2013. Recycling and composting rose from 17% in 1995 to 42% in 2013, and incineration's contribution to the MSW disposal stream rose from 14% in 1995 to 25.6% in 2013. In EU over 400 waste-to-energy facilities treated 56.2 million tons of the total waste produced in 2013 [5–7].

Thus, comparing the US and EU waste management experiences it appears that EU, which had 56.2 million tons incinerated in 2013, relies much more on incineration than USA, which treated thermally 29.4 million tons in 2012, almost half of the EU quantity. In terms of recycling, both USA and EU appear to have reached almost similar targets; 86.6 million tons were recycled in USA in 2012 versus 92 million tons in 2013 in EU, or in percentages of the total waste stream 34.5% in 2012 and 42% in 2013, respectively. In short, the amounts to be disposed of, after recycling, remained extremely high both in USA (164.3 million tons in 2012) and in EU (122.5 million tons in 2013). Similar projections of increasing global MSW with almost doubling of the produced waste by 2025 were reported by the World Bank, where the per capita rate is expected to increase from 1.2 kg/person/day to 1.42 kg/person/day by that year [9]. Thus, despite the impressive improvements in recycling and irrespectively of the landfilling/incineration mixture differences between USA and EU the fact remains that incineration appears to be the only viable alternative to landfilling for developed economies.

An important aspect of incineration is the generation of heat, steam, and/or electricity from waste. MSW can be incinerated as is, or preprocessed with energy recovery depending on the quantity and thermal potential of the collected material, efficiency of the processing system, and type of energy produced. Energy efficiency can range from 80% if only heat is produced, to between 20% and 30% if cogeneration of steam and electricity is needed, to about 20% if pure electricity from MSW is desired [13]. For Gulf Region countries that utilize close to 23% of their energy for desalination, waste-to-energy technologies are well suited and can be combined with membrane and thermal desalination systems, thus relieving the pressure on the power grids, provide a sustainable source of drinking water to countries with limited water resources, and reduce the carbon footprint of desalination plants that are currently relying heavily on fossil fuel [8,38].

Denmark constitutes a case study in that it has, perhaps, the most efficient waste management system in Europe with recycling rates of over 65% and landfilling almost phased out at 8% of the total waste. At the end of 2003 Denmark had 3.64 million tons of waste incinerated in the 29 waste-to-energy facilities with 1 ton of waste producing, on the average, 2 MWh heat and 2/3 MWh electricity [14].

The problem of the incineration plants as structures that occupy a large area and dominate the urban environment is typified by the Spittelau facility in the city of Vienna, Austria. Vienna, which was awarded in 2010 the prize of “world city closest to sustainable waste management,” generates approximately 1 mi tons of waste per year. About 60% of this is thermally treated in four waste incineration plants, which cogenerate energy for district heating and cooling, and electricity. The Spittelau incineration plant (Fig. 1) posed significant challenges from an architectural point of view during its refurbishment after a fire destroyed it in 1987. These included its location in the middle of the city in order to provide heat to a nearby hospital; its proximity to important city landmarks and the Danube River; its 126 m tall chimney; and the size of the facility, which covers an area of 17,500 m² and includes a 7000 m³ bunker, where over 250 delivery vehicles discharge their waste every day. The Spittelau can process 250,000 ton of waste per year [10–12].

The thesis of this paper is that despite the current strides in recycling significant waste amounts will remain to be disposed of and thermal treatment appears to be the dominant disposal option for the foreseeable future. It will be extremely challenging to curb the volume of the after-the-recycling waste in view of the anticipated population growth and as developing countries adapt consuming patterns resembling those of the USA and the EU. Concomitant to this is the size and space of the incineration facilities and the need to be located close or within the urban environment. This point constitutes the

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