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Research Paper

Sustainable Domestic Solid Waste Management in Jeddah, Saudi Arabia

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Abstract: In Saudi Arabia, as a result of rapidly developing population, urban development, demands for more prosperous life and technological developments, the amount of wastes generated, and the amount of these wastes are rapidly increasing. Methods used in today's conditions for removing these domestic wastes; irregular solid waste storage and solid waste storage. In this study, the establishment of a modern waste recovery facility instead of solid domestic waste storage and the technical and economic calculations of the energy production installation of this facility are examined. Such an integrated recycling system has been determined by means of technical and economic analysis of the average composition of the organic matter content of Jeddah (paper, plastic, glass, metal) and the amount of waste that can be disposed of waste disposal and power generation facilities. Based on these technical data; The main investment cost determined for the start of the facility is 201.096.000 USD. The annual income of the plant is 122.033.960 USD and the expense of the plant is 14.733.088 USD and the net income of the plant is predicted to be 107.300.872 USD. Finally, the simple repayment period for this investment was calculated as 1.87 years.

Keywords: *Household waste, obtaining energy from biogas and /or wastes, recycling*

Introduction

All kinds of environmental problems that we have to deal with today and the reasons and the actual sources of these problems are very different from each other. If we define the main causes of environmental problems; rapid migration from rural to urban, urbanization and poorly planned industrialization. Rapidly developing population, industrial development and distorted urbanization cause quite a lot of waste problems. Today, one of the most important environmental problems is the waste management generated by the various activities of the public. The problem of waste problems must be completely solved and managed. (Kaya *et al*., 2009, Kaya *et al*., 2008, Bascetincelik *et al*., 2009, Bascetincelik et al., 2009, Kaya et al., 2008, Recebli et al., 2015, Ozkaymak et al., 2016, Koymatcika *et al*., 2018, Abu-Qudais & Abu-Qdais, 2000, Morris & Waldheim, 1998).

Solid waste problems caused by human activities and methods used to solve these problems; domestic storage, waste storage, composting, recycling and incineration activities that are not carried out within a specific plan. In the Landfill Directive (1999/31 / EC) (Waste Management Action Plan, 2008-2012), one of the EU Landfill Directives has identified its technical requirements for the regular storage of wastes, and fully eliminates or minimizes the impacts of waste on the environment to carry out storage activities. The primary waste management method will be to minimize the waste generated by our separation at the waste source. Secondary method; recycling and / or composting methods will also be combined to produce bio-energy from wastes. Although methods such as incineration and solid waste management are acceptable workarounds for solid waste, these methods are at the bottom of the priority list. Bioenergy generation from waste and compost, recycling and re-use of resources are the highest solution types (Erdem *et al*., 2010, Ekinci *et al*., 2010, Yaldiz *et al*., 2011,).

In this study, technical and economical domestic and / or solid waste recovery, waste disposal and feasibility study of an energy production facility using these solid wastes were carried out. As a result, in an average household waste composition of Jeddah municipality, the amount of recyclable waste and the content of organic materials were found. In the light of this information; possible initial investment cost, estimated annual income, annual expenditure and estimated amortization period are determined.

Basic Materials and Applied Methods

Applied Steps: In the first stage, domestic waste comes from its sources to dissolution and treatment plants. This step follows the other step in which solid waste is reduced into dimensionally smaller pieces

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into organic and recyclable pieces. Organic parts are sent to be converted into biogas or fertilizer in fermentation units (wet or dry fermentation). Biogas is used to produce the electricity via gas engine and generator group is supplied to the city network, the rest can be used for various needs in the plant. In addition, some of the heat produced from biogas can be used for fermentation and heating, while the rest can be used for heating of residential areas, buildings, kindergartens, schools, hospitals, public places and heating greenhouses. The flowchart of solid waste recovery, waste disposal and energy generation facility from waste is shown in Figure 1.

Figure 1. Solid / domestic waste recovery, recycling and flow chart of the power plant.

In the recycling section, first all the metals are taken up magnetically and each of the waste such as plastic, paper, glass is separated into groups, the rest of which is also separated into another group. For plastic wastes, they are first separated according to their types and then converted to burrs, finally plastics that are converted to a granular form can be made into secondary raw materials for the economy. On the other hand, one of the methods used by glass manufacturers for energy saving is the recovery of used glass bottles. Broken glasses are melted together with other raw materials for recovery. The more intense glass is used in the furnace; the less heat is required for the process. When the glass products used in the melting furnace are melted, there is a 25% reduction in energy consumption. For recycled paper, the paper fibres are separated in water to be prepared in the paper slurry. If desired, fibre-free impurities and particles are removed from the mixture, as a result, the paper fibres prepared for processing may be used in the production of recycled paper.

Determination of the Amount and Composition of Solid or Household Wastes

The amounts of the Jeddah municipality recyclable wastes were obtained by using domestic solid wastes and the composition amounts of these wastes. In the calculation of waste amount, the population of Jeddah municipality was taken as 3.500.000 people, the amount of waste produced per day was considered as 1.5 kg and all calculations were made considering that the annual waste amount would be approximately 1.900.000 tons. The basic waste composition and the amount of recyclable waste for the calculations are shown in Table 1.

Table 1. Solid Waste compounds and amounts to be recycled referenced in calculations in according to product groups

The product group for Waste Composition	The Amount of Waste in according to product group (%)	Quantity of Recyclable Waste (Ton/Year)
Paper and carton	20	380,000
Plastic	15	285,000
Glass	2.9	55,100
Metal	1.9	36,100
Aluminium	0.80	15,200
Wood	1.98	37,620
Textile	1.93	36,670
Leather	0.3	5,700
Organic Waste	48	912,000
Other	7.14	136,610

Incomes

Paper Incomes: In this facility, 380,000 tons of paper waste of different types will be recycled annually. Considering that 1 ton of paper is 125 US Dollar in this recycling process:

$$\text{Annual Earnings} = \frac{380{,}000 \text{ tons of paper}}{\text{a year}} \times \frac{125 \text{ US Dollar}}{1 \text{ ton of paper}} = 47{,}500{,}000\ \$$$

Plastic Incomes: In this facility, 285,000 tons of plastic waste of different types will be recycled annually. Considering that 1 ton of plastic is 95 US Dollar in this recycling process:

$$\text{Annual Earnings} = \frac{285{,}000 \text{ tons of plastic}}{\text{a year}} \times \frac{95 \text{ US Dollar}}{\text{a ton of plastic}} = 27{,}075{,}000\ \$$$

Glass Incomes: In this facility, 55,100 tons of glass waste of different types will be recycled annually. Considering that 1 ton of glass is 60 US Dollar in this recycling process:

$$\text{Annual Earnings} = \frac{55{,}100 \text{ tons of glass}}{\text{a year}} \times \frac{60 \text{ US Dollar}}{\text{a ton of glass}} = 3{,}306{,}000\ \$$$

Metal Incomes: In this facility, 36,100 tons of metal waste of different types will be recycled annually. Considering that 1 ton of metal is 240 US Dollar in this recycling process:

$$\text{Annual Earnings} = \frac{36{,}100 \text{ tons of metal}}{\text{a year}} \times \frac{240 \text{ US Dollar}}{\text{a ton of metal}} = 8{,}664{,}000\ \$$$

Aluminium Incomes: In this facility, 15,200 tons of aluminium waste of different types will be recycled annually. Considering that 1 ton of aluminium is 1000 US Dollar in this recycling process:

$$\text{Annual Earnings} = \frac{15{,}200 \text{ tons of metal}}{\text{a year}} \times \frac{1.000 \text{ US Dollar}}{\text{a ton of metal}} = 15{,}200{,}000\ \$$$

The Electrical Energy Incomes: We have assumed that the annual amount of organic waste is 912,000 tons and the daily use of these organic wastes is 2,500 tons. In the light of the information that we can obtain 140 m^3 biogas from 1 ton of organic waste;

$$\text{The annual amount of produced biogas} = 912{,}000 \times 140 = 127{,}680{,}000\ \text{m}^3$$

$$\text{The annual production of electric} = 2.1 \times 127{,}680{,}000 = 268{,}128{,}000 \text{ kWh}$$

$$\text{Electric power of the facility} = \frac{268{,}128{,}000}{8{,}000} = 33{,}516 \text{ kWe}$$

Considering that one kWh of electricity is 7 $ cents and 8000 hours of work per year, the other detail calculations are as follows:

$$\text{Electrical Incomes} = 268{,}128{,}000 \text{ kWh} \times \frac{0.07 \text{ Dollar}}{\text{kWh}} = 18{,}768{,}960\ \$$$

Thermal Energy Incomes: The annual thermal energy will be equal to the annual electricity amount.

$$\text{Thermal energy incomes} = 0$$

Carbon Trading: $\text{Carbon trading income} = \text{Built} - \text{in capacity (kW)} \times \text{Working hours} \times \text{Green certificate fee} \left(\frac{0.00 \text{ Euro}}{\text{kWh}}\right)$

$$\text{Carbon trading income} = 3{,}734.64 \text{ kW} \times 8{,}000 \text{ h} \times 0.00 \left(\frac{\text{USD}}{\text{kWh}}\right) = 0$$

Compost Incomes: An annual compost product of 304,000 tons will be obtained. This product is taken into account as 5 Euro per tonne

$$\text{Compost revenues} = \frac{304{,}000 \text{ a ton}}{\text{a year}} \times \frac{5 \text{ US Dollar}}{\text{a ton}} = 1{,}520{,}000\ \$$$

$$\text{Total Revenues} = \frac{122{,}033{,}960\ \$}{a\ year}$$

Spending

Facility Maintenance Spending: It is decided that the possible maintenance costs of the facility should be 2% of the total investment cost. Therefore,

$$\text{The maintenance spendings for one year} = 201{,}096{,}000 \times \frac{2}{100}$$

$$\text{The maintenance spendings} = 4{,}021{,}920\ \$$$

Insurance and Taxes: Insurance and taxes can be taken into account as 0.5% of the total investment cost. Thus, spending on annual insurance and taxes are 1,005,480 $.

Workmanship: Taking into account that an employee of 200 people and all expenses of each employee including tax and insurance is 1500 USD, the total labour expenses are 3.600.000 USD.

Transportation Spending

For transportation costs, 0.25 $ per ton is foreseen at the facility; therefore, the total annual expenditure is 475,000 $.

Domestic Consumption of Electricity Costs: 30% of the electricity generated from waste recovery in the facility was considered suitable for the consumption of the facility. Therefore, the total cost of electricity consumption of the facility is 5,630,688 USD.

Installation Cost

In this facility, where 1 kW power is 6000 USD and total investment cost is 201.096.000 USD, all income and expenses are listed above and also listed in Table-2 below.

Table 2. Incomes & Spending for the facility

Component of Facility	Calculation Technique	Example	Cost	Unit
Installation Sum	Built-in capacity (kW) * investment spending ($/kW)	3734.64 kWe×6,000 USD	201,096,000	Dollar ($)
		Spending		
Facility maintenance expenses	(Total investment spending) * % 2	18,673,200 $ 2%	4,021,920	$/yearly
Insurance and taxes	Total investment spending× % 0.5	18,673,200 $ × 0,5%	1,005,480	$/yearly
Workmanship	Person× 12 Months × 1.500 €	20 ×12×1500 $	3,600,000	$/yearly
Onsite transportation costs	Transportation spending	1,5 $/ton/yearly × 180,000 tons	475,000	$/yearly
Domestic consumption of electricity Costs	Production power×%30× Annual working hours × cost	3734.64×0,30×8,000×0.10	5,630,688	$/yearly
Annual total sum		14,733,068		$
		Incomes		
Electricity for sale	Built-in capacity (kW) × (%80) Working hours × The price of electricity	3734.64 kW × (8,000 h × 0.10 €/kWh	18,768,960	$/yearly
Carbon trading	Built-in capacity (kW) × Working hours × Green certificate fee	3734.64 kW × 8,000 h × × 0.01 €/kWh	0	$/yearly
Heat usage	Heat of cogeneration (kW) × Working hours × 0,01 €/kWh	3734,64 kW × 8,000 ×0.01 €/kWh	0	$/yearly

Organic fertilizer for sale	20,000 (t/a year) × 5 €/t	50,000 t/yearly × 5 €/t	1,520,000	$/yearly
Paper incomes	Sum for one year × 30 €/t	4,320 t/yearly × 30 €/t	47,500,000	$/yearly
Plastic incomes	Sum for one year × 100 €/t	6,840 t × 100 €/t	27,075,000	$/yearly
Glass incomes	Sum for one year × 17,5 €/t	3,780 ton× 17.5 €/ton	3,306,000	$/yearly
Metal incomes	Sum for one year × 125 €/t	3,060 ton×125 €/ton	8,664,000	$/yearly
The annual total incomes		122,033,960		$
The annual profit	(Incomes-Spending) /a year	(122,033,960-14,733,068) USD/a year	107,300,872	$
Amortization period (for one year)	Total investment sum / Annual profit	201,096,000/ 107,300,872	1.8741 (≈22,5 months)	a year

Conclusions

In this study, detailed feasibility studies of the waste recovery and storage project of Jeddah Municipality have been made in terms of technical and economic aspects and related cost analyses have been presented for the facility. In the light of all this information, the following findings are summarized.

*As a result of the establishment of a waste recovery or recycling facility instead of landfill, household wastes of a municipality will be separated at their source as much as possible and then become economical materials such as glass, metal, paper and plastic. Thanks to recycling, biogas and fermented fertilizer production will be realized from organic wastes. After these processes, electricity and heat can be produced from biogas and thus there will be no need for regular storage of municipal wastes.

*Thanks to the technology proposed in this study, separation of wastes can be achieved, recycled materials can be sold as a result of recycling, compost production can be provided from biogas and organic wastes, electricity and hot water will be produced from the biogas produced. Approximately 30% of the total electricity and heat generation produced in the facility can be used as energy within its own structure and the other 70% can be sold.

*The main investment sum of the facility is predicted to be 201.096.000 USD, the annual income of the facility is estimated to be 122.033.960 USD, the expense of the facility is 14.733.088 USD and the net revenue of the facility is predicted to be 107.300.872 USD. In this case, the repayment period for the investment was predicted as 1.87 years (≈ 22.5 months)

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