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The feasibility analysis of household solid waste recycling and an energy production facility installation in technical and economic point of view

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ABSTRACT

In Turkey, the types and quantities of waste that produced by people is increasing rapidly as a result of increasing population, urbanization, rising living standards and technological developments. The methods that are used to solve the problem of household solid waste elimination are: irregular storage, landfill, composting, reuse, recycling, retrieval and incineration. In our country, domestic waste disposal methods are irregular and regular storage. While sanitary landfill method implementations are on the processing in our country, the EU countries have already been abolishing this method and its applications areas gradually. In this study, instead of landfill, installation of a modern solid waste retrieval, disposal and energy production facility installation has been analyzed in technical and economic point of view. To make a technical and economic analysis of such an integrated recycling, disposal and energy generation facility, the average composition and the amount of waste, household waste, recyclable (paper, plastic, glass, metal) and organic matter contents that belong to a municipality have been determined. Based on this information; investment cost of the facility, annual revenue, annual expenditure and repayment period have been calculated.

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1. Introduction

The environmental problems that we are facing today are very different, as their resource and developments. Generally, the main reasons for these ongoing environmental problems are; migration from rural areas to cities, unplanned urbanization and irregular industrialization [1]. Such cases as rapid population growth, industrial development and urbanization, have brought about solid waste problems in cities. Today, one of the most important environmental problems is waste management that produced by the people's various activities. The issue of waste problems should be fully resolved and managed [2].

The methods that used in eliminating the problem of solid waste, obtained as a result of human activities are; irregular storage, landfill, composting, reuse, recycling, recovery and incineration. One of the EU Landfill Directives is Well-ordered Storage Directive (1999/31/EC), which specifies technical requirements for storage of waste regularly, and aims to eliminate or reduce the effects of waste storage activities on the environment as much as possible.

The first priority solid waste management system is to reduce the amount of produced waste by the separation in its source. The second priority is the production of bio energy from waste, including composting methods such as recycling and recovery. Although disposal methods such as incineration and landfill waste management are applicable to solid waste and acceptable technologies, they are in the lower ranks in the priority list. Bio energy production from waste and composting are the highest forms of recycling and re-use of resources [1].

In this study, feasibility analysis of a solid waste recycling, disposal and energy production facility installation has been carried out in technical and economic point of view. For this purpose, average household waste compositions, the recoverable amount of waste and organic matter content that belong to a municipality have been determined. Based on this information; investment cost of the facility, annual revenues, annual expenditures and repayment period is calculated.

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2. Recommended Technology

The solid waste is brought from its sources to the separation and refining facilities. This follows the process that solid waste is reduced in size and separated as organic and recyclable parts. The organic parts are sent for the fermentation (wet or dry fermentation) units to produce biogas and manure. The produced biogas is combusted in gas engine and generator group to generate electricity and heat, a part of the produced electricity is used for their own needs in the facility the rest is given to the city network. Also, the part of the generated heat is used for the heating of the fermenters and the rest is used for the heating of nearby located residential areas like housing, schools, hospitals, etc., or in greenhouses. The flow scheme of a solid waste recycling, disposal and energy production facility is given in Figure 1.



Figure 1: The flow scheme of a solid waste recycling, disposal and energy production facility.

In the recycling part, first of all the metals are separated by taken magnetically, the rest of waste like the plastic, paper, glass, etc., each group is also separated. As for plastics, according to their types, they are separated and converted to the burr, then developed into a granular form, so they can be brought into the economy as secondary raw materials. On the other hand, one of the methods that glass producers are using to save energy is recovering of the used glass bottles. The broken glass materials are melted with the other raw materials together for the recovery. The more amount of glass is used in the hearth, the less heat is required for the process. It is possible to provide 25% reduction in energy consumption, when wholly used glass products are melted in the melting furnace. To make recycled paper, the paper fibers are separated in water for the preparation of paper sludge. If it is necessary, foreign substances that lack of fibers are cleaned from the mix, then the paper fibers which are ready for the process, are used in the production of recycled paper.

2.1. Solid Waste (Garbage) Quantities and Composition of Waste

The recyclable waste amounts that belong to a municipality have been calculated by using the amount of domestic solid waste and waste composition. When calculating the amount of waste, "Solid Waste Action Plan of the Ministry of Environment in 2008-2012" has been taken into consideration as a reference [3]. According to "Solid Waste Action Plan of the Ministry of Environment in 2008-2012" the

population of this municipality is 1.400,00 and the amount of waste that produced by a person per day is 1 kg and the annual amount of waste has been calculated as 511,000 tons. The waste composition and quantities of recyclable waste that have been taken as a basis for calculations are given in Table 1.

Table 1. The waste composition and quantities of recyclable waste that have been taken as a basis for calculations

The Waste Composition	The Amount of Waste (%)	Quantity of Recyclable Waste (a Ton/a Year)
Paper	4,29	21.922
Plastic	9,45	48.289
Glass	2,68	13.694
Metal	1,87	9.555
Organic Waste	42,84	218.912
Other	38,87	198.625

3. The Revenues

a. Paper Revenues:

21,922 tons of paper type waste will be produced annually at the facility. If a tone of the paper can be taken into account as the price of Euro 30:

Annual Earnings=21.922 tons of paper/a year * 30 Euro/ a ton of paper=657.657 Euro

b. Plastic Revenues

48,289 tons of plastic type waste will be produced annually at the facility. If a ton of the plastic can be taken into account as the price of Euro 100:

Annual Earnings=48,289 tons of plastic/a year *100 Euro/a ton of plastic=4,828,900 Euro

c. Glass Revenues

13,694 tons of glass type waste will be produced annually at the facility. If a ton of the glass can be taken into account as the price of Euro 17.5:

Annual Earnings= 13694 tons of glass/a year* 17.5 Euro/a ton of glass=239,645 Euro

d. Metal Revenues

9,555 tons of metal type waste will be produced annually at the facility. If a ton of the metal can be taken into account as the price of Euro 125:

Annual Earnings=9555 tons of metal/a year*125 Euro/a ton of metal=1194 375 Euro

e. The Electrical Energy Revenues

The annual amount of organic waste is to use is 218.912 tons. For a daily amount of this is about 600 tons. 125 m³ biogas can be produced from a ton of organic waste.

The annual amount of produced biogas= 218.912*125= 27.364.000 m³

The annual production of electric= 61.569.000 kWh

Electric power of the facility =61.569.000/8000= 7.696 kWe

If a kWh of electricity can be taken into account as the price of 10 Euro cents and the annual working hours of the event is 8000, the calculations can be carried out as follows:

Electrical Earnings = 61569000 kWh * 0.10 Euro/kWh= 6.156.900 Euro

f. Thermal Energy Revenues

Annual thermal energy can be equal to the amount of electricity.

Thermal energy earnings = 61569000 kWh*0.01 Euro/kWh= 615.690 Euro.

g. Carbon Trading

Carbon trading income = Built-in capacity (kW)* Working hours * Green certificate fee
= 7696 kW * 8000 h * 0.01 Euro/kWh = 615.680 Euro

h. Compost Revenues

About 140,000 tons of compost products are to be obtained annually. The annual economic value of this, 5 Euro/a ton can be taken:
140000 a ton/a year * 5 Euro/a ton = 700 000Euro

Total revenues: 15 008 847 Euro/a year

4. The Expenses

a. Facility Maintenance Expenses

It has been understood that 2 % of the total investment expense can be considered as maintenance costs in the discussions with the ongoing operation of the facilities. Therefore,

The annual facility maintenance expense= 34.632.000 *2/100

Annual maintenance costs=692.640 Euro

b. Insurance and Taxes

For the insurance and taxes 0.5% of the total investment amount can be envisaged as an expense. In this case, the annual expenditure is € 173.160.

c. Labor Force

It is envisaged that 50 people can work at the facility. For each staff, including tax and insurance expenses are foreseen in the Euro 2500, total expenditure is € 2.700.000.

d. Transportation Expenses

For transportation costs, 1.5 Euro per ton is foreseen at the facility; therefore, the total annual expenditure is € 328 368.

e. Domestic Consumption of Electricity

30% of total produced electricity is foreseen for the consumption at the facility for its own use; accordingly, the amount of annual consumption cost is 1.847.040 Euro.

5. Installation Cost

It has been foreseen that the cost of such a facility for the power of 1 kWe is 4.500 Euro and 34.632.000 Euro can be calculated as total account. The income and expense summary of the facility are given above and listed below in Table 2.

Table 2. The income and expense summary of the facility

Facility Component	Calculation Method	Example	Cost	Unit
Installation Cost	Built-in capacity (kW) * investment expenses (€/kW)	7.696(kW)×4.500(€/kW)	34.632.000	Euro (€)
Expenses				
Facility maintenance expenses	(Total investment expenses) * % 2	34.632.000 € 2%	692.640	€/a year
Insurance and taxes	Total investment expenses × % 0,5	34.632.000 € × 0,5%	173.160	€/a year
Labor force	Person× 12 Months × 1.500 €	50 ×12×2500 €	2.700.000	€/a year
Onsite transportation costs	Transportation expenses	1,5 €/ton/a year × 218.912 ton	328.368	€/a year
Domestic consumption of electricity	Production power×%30× Annual working hours × cost	7696 ×0,30×8.000×0,10	1.847.040	€/a year
Annual total costs	5.741.208			€
Revenues				
Electricity for sale	Built-in capacity (kW) × (%80) Working hours × The price of electricity	7.696 kW × (8.000 h × 0,10 €/kWh	6.156.900	€/ a year
Carbon trading	Built-in capacity (kW) × Working hours × Green certificate fee	7.696 kW × 8.000 h × × 0,01 €/kWh	615.680	€/ a year
Heat usage	Heat of cogeneration (kW) × Working hours × 0,01 €/kWh	7.696 kW × 8.000 ×0,01 €/kWh	615.690	€/ a year
Organic fertilizer for sale	20.000 (t/a year) × 5 €/t	140.000 t/a year × 5 €/t	700.000	€/ a year
Paper revenues	Annual amount × 30 €/t	21.922 t/a year × 30 €/t	657.657	€/ a year
Plastic revenues	Annual amount × 100 €/t	48.289 t × 100 €/t	4.828.900	€/ a year
Glass revenues	Annual amount × 17,5 €/t	13.694 ton× 17,5 €/ton	239.645	€/ a year
Metal revenues	Annual amount × 125 €/t	9.555 ton×125 €/ton	1.194.375	€/ a year
The annual total revenues	15.008.847			€
The annual profit	(Revenues-Expenses) /a year	(15.008.847-5.741.208) €/a year	9.267.639	€
Repayment period (a year)	Total investment cost / Annual profit	34.632.000 / 9.267.639	3,73 (≈45 months)	a year

6. Conclusions

In this study, the technical and economic etude of a municipality's domestic waste landfill project, which is transformed into recycling and disposal project has been carried out. The results of the study can be summarized as follows;

Instead of landfill, with the establishment of a disposal and recycling facility, the household waste of a municipality will be separated at its own source as much as possible, and then materials that have the economic value like glass, metal, paper and plastics will be recycled. The production of biogas and fermented manure will be realized from organic waste. After these processes there will be electricity and heat production from biogas. Therefore, the need to store the municipality's waste regularly will not be required to a large extent.

With the proposed technology, separation of waste, the selling of recyclable ones, biogas and compost production from organic waste, electric and hot water production from produced biogas will be realized. Approximately 30% of the total production of electricity and heat that have been produced inside of the facility is used for its own internal energy, and the other 70% part of total energy has the opportunity to be sold.

The initial investment cost of the facility is calculated as 34,632,000 Euro. The annual revenue of the facility is 15,008,847 Euro and the expenditure of the facility is 5,741,208 Euro, the net income of the facility is estimated as 9,267,639 Euro. In this case, a simple payback period of this investment has been calculated as 3.73 years (\approx 45 months).

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