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Short Communication

Feasibility study of different methods of energy extraction from Ardabil urban waste

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ABSTRACT:

In this research costs and revenues of each technology in economic and environmental scenarios are studied and in order to compare technologies economically, present net value method (the ratio of present net benefits to costs) in six scenarios are used. As a result, the highest revenues (by avoiding environmental cost related to electricity production of 115.72 dollar on tone and without avoided environmental cost related to electricity production 86.87) are related to anaerobic digestion technology and the highest present net value of benefits to costs in first scenario is related to the anaerobic digestion of 1.10 dollars on tone (without environmental costs, electricity revenues, fertilizer and CDM) and in the second scenario it is related to anaerobic digestion of 1.15 dollar on tone (without environmental cost and revenues from electricity, fertilizer and CDM sale) and in the third scenario it is related to anaerobic technology (with environmental cost and revenues from electricity sale). Municipal wastes are byproduct of social life which its correct management is one of the main concerns of urban and national authorities. On the other hand environmental problems caused by such practices such as greenhouse gas emission and production of pollutants have attracted the attention of International organizations and countries' authorities to waste management. Energy production from wastes is one of the selected solutions of urban managers in the area of sustainable management of wastes. In the fourth scenario it is related to anaerobic digestion of 1.4 dollars on tone with environmental costs and revenues from electricity, fertilizer and CDM and in the fifth scenario it is related to anaerobic digestion of 1.45 dollars on tone with environmental costs and revenues from electricity, fertilizer and CDM. Therefore the most economical technology of anaerobic digestion and gasification technology is type 1 and 2 of waste burning and waste landfill. With respect to environmental comparison of technologies using AHP method and expert choice software the most environmental technology is gasification. In order to combine economic and environmental factors we used the ratio of present net benefits to costs in six scenarios. The most economic and environmental technology is anaerobic digestion technology.

Keywords:

Energy extraction of waste, Landfill gas, Anaerobic digestion, Waste incinerator, Gasification.

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INTRODUCTION

From previous years, replacement of fossil fuels with renewable energies has begun in the world. The exploitation of these resources is due to the limitation of fossil energy and environmental necessities due to the consumption of fossil energies including weather changes, increasing greenhouse gases and acidic rain and many other things that show the importance of using renewable energies. Necessity to pay attention to the environmental problems caused by domestic, industrial and chemical waste is obvious. This necessity arises from the fact that the conventional relationship between man and the environment in biosphere is moving out of form of equilibrium and balance due to a great deal on humans. There is a relationship between human and environment that rational relationship between them is an essential condition on the life of both (Panwar and Kothari, 2011). Urban waste management in all countries imposes heavy costs on government. These costs in addition to economic problems have many environmental problems which is a threat in urban waste management. Therefore urban managers try to find new ways for urban waste management and change threats into opportunities. Energy production from wastes is among the selected solutions. Also the use of these wastes in addition to energy production can reduce the environmental and health problems caused by inappropriate waste management (Tyagi and Lo, 2013). The generation of energy from waste in recent years has attracted the attention of Government of Islamic Republic of Iran. This caused that supportive mechanisms for producing this kind of energy are predicted in the fourth plan. Obviously it is not feasible without considering the requirements for solid waste management. For this purpose waste management organization has recommended and validated four different technology energy combinations of the most energy-efficient products needed for energy production. These technologies include: 1. Landfill gas extraction; 2. Waste incineration; 3. Anaerobic digestion; 4. Gasification. The result of reviewing these options is that the most suitable option for use in the city of Ardabil is economic considerations and on the other hand the choice of cheapest option requires cost effective environmental solutions. In order to be able to attract investors it is necessary to reduce the risk of investment in energy extraction from waste in order to provide a comprehensive waste management plan in Ardabil as prerequisite for the next investment. In this regard for the sake of better investigation hypotheses have been proposed as follows:

It is possible to use energy extraction methods in municipal waste disposal in Ardebil.

- Anaerobic digestion can be one of the best ways to extract energy from Ardabil waste streams in clean and renewable energy production.
- There are economic, environmental and social justifications for energy extraction.
- A combination of methods can be used for energy extraction from urban waste.
- Landfill biogas can be a good way to extract energy from urban waste.

Table 1. The costs and revenues of the waste landfill center

S. No	Cost types	$/ton
1	Annual initial investment cost	2
2	Environmental cost of pollutants	4.13
3	Earnings from electricity sales	0
4	Earnings from environmental costs associated with production	8.655
5	Net value: total costs with environmental costs	40.36
6	Net value: total costs without environmental costs	1990
7	Total revenue	9.13

The basics of research

According to the topics and the title of the research, these definitions are mentioned:

Waste

All solids, liquids and gases (other than sewage)

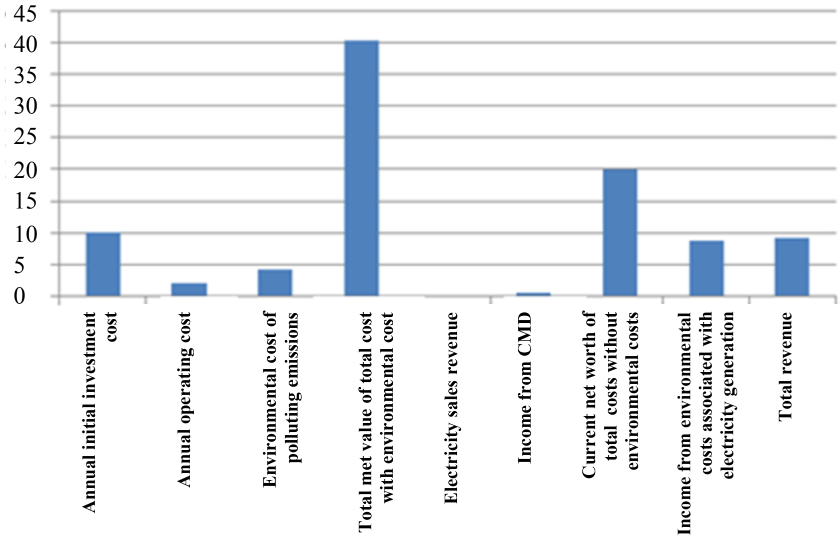

Figure 1. Urban waste disposal center costs

that directly or indirectly derived from human activity and regarded as waste by producers (Patnaik, 2010).

Waste management

Waste management is to provide an insight into the use of new policies and technologies for waste management in order to manage and reduce waste effects in the environmental, health and socioeconomic fields in order to achieve integrated waste management (Hoornweg and Bhada-Tata, 2012).

Energy extraction from waste

Generally energy recovery is achieved through burning wastes. The wastes can be recycled using following methods:

- Recycling and re-rotation of materials and thus reducing energy consumption for production
- Gas extraction from the landfill for energy production
- Gas extraction from large digestion (biogas)
- Direct burning of wastes
- Generate liquid fuel (bio-tanol) from the waste
- Pyrolysis of waste
- Generation of waste derived fuels (RDF)

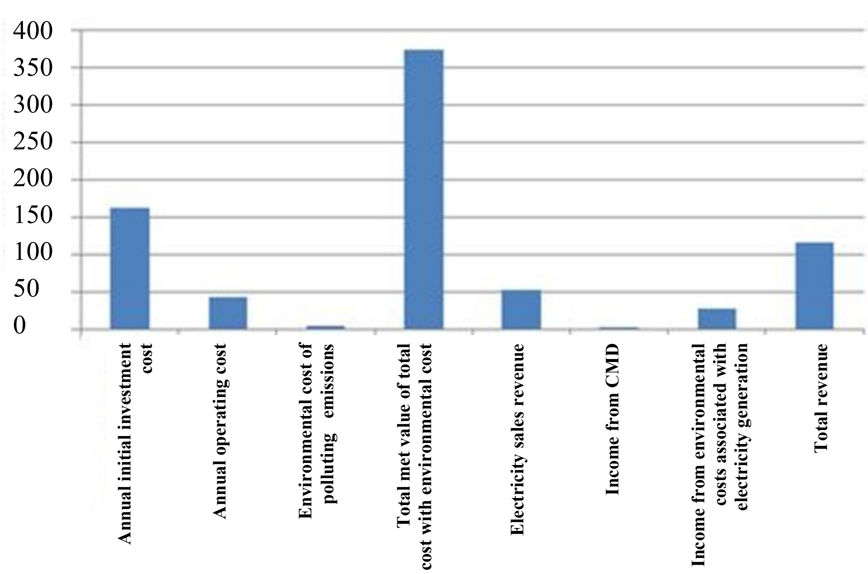

Figure 2. Summary of costs and anaerobic digestion (dollars on tons of municipal waste)

Table 2. Present net value to the expense of waste landfill technology

Scenario / Method	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
$/ton	0	0.11	0.05	0	1.12	2.27

Table 4. Net present value of benefit-cost for anaerobic digestion technology

Scenario / Method	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Anaerobic digestion	1.10	1.15	1.09	1.04	0.45	1.53

Landfill gas

In the case of landfill of household waste and in the absence of oxygen, the organic part of buried waste and a combination of methane, carbon dioxide, hydrogen, nitrogen and small amount of chlorofluor and moisture are produced. Generally gas production begins after two month from landfill site and lasts for up to 100 years (Thabet *et al*., 2010).

Anaerobic digestion

The process of transformation of biogas takes place through the disintegration of bacteria with the absence of air. The main combination of this biogas is carbon dioxide and methane. This technology is applied for refining the biomass like municipal solid waste. The most significant sample of this process is the landfill waste center (Caputo *et al*., 2005).

Biogas

The organic materials turn to the smaller molecules during the anaerobic digestion process.Biogas is the final production of this process. This gas is able to replace the fossil fuel (Taleghani and Kia, 2005).

Review of the related literature

There were varieties of studies on the basis of energy conversion from the municipal solid waste. According to Hall (2014), many countries in the southern of middle East and Southeast Europe have potential of technical and economic resources in order to create renewable energy. Based on the mentioned studies, the total amount of economic potential of biomass will reach 23.7 in 2050. The amount of economic potential of power generation from the municipal solid waste in the years 2000, 2010, 2030, 2040, 2050 are as the following values: 9.33, 11,46, 13.03, 14.69, 15.94 TWH which is equal with the following values 1060, 1330, 1630, 1855, 2090, 2260 Sunggyu *et al*. (2014), argued about the evaluating the potential of electricity generation from the biogas power plant. He investigated the applications of these power plants and the related economic and environmental

Table 3. Summary of costs and anaerobic digestion (dollars on tons of municipal waste)

S. No	Cost types	$/ton
1	Annual initial investment cost	162.5
2	Environmental cost of pollutants	42.46
3	Present net present value of the total cost or environmental cost	4.05
4	Earnings from electricity sales	52.5
5	Earnings from environmental costs associated with CMD	3.72
6	Income from environmental costs associated with power generation	28.85
7	Net value: total costs with environmental costs	392.90
8	Net value: total costs without environmental costs	472.9
9	Total revenue	1150.73

Table 5. The summary of costs and incomes of dollar per ton for municipal solid waste

S. No	Type of costs	$/ton
1	Annual initial investment cost	283.41
2	Annual operational cost	51.35
3	Environmental cost	5.35
4	Electricity sale revenue	31.29
5	Revenue from greenhouse gas emission reduction (CDM)	2.46
6	Revenue from environmental cost associated with power generation	17.20
7	Net present value of total costs with environmental cost	564.34
8	Net present value of total costs without environmental cost	573.71
9	Total revenue	50.95

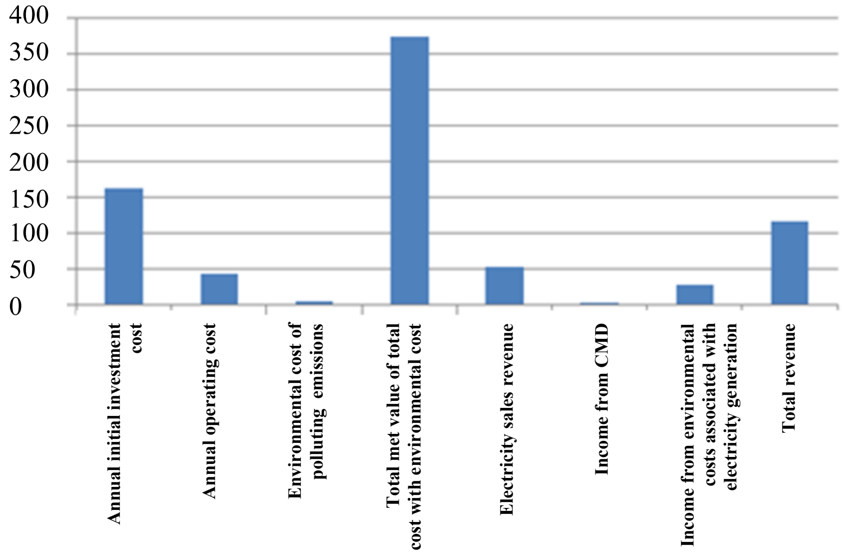

Figure 3. The summary of costs and incomes of MSW incinerator in dollar per ton

aspects. The case study is Mashhad city. He also studied about the feasibility of these power plants based on the municipal solid waste in Mashhad. The power of installation of power plant in Mashhad City equals with 11.67 MW.

MATERIALS AND METHODS

Data collection is through the following ways: referring to the research centers like universities and Iranian Department of Environment, Ministry of Energy, and municipality. Data were also collected by means of internet surfing. Some information is needed in the process of collecting data. They are as the following: incinerator, gasification by relying on the production of their derivatives including power production, agrochemical in the anaerobic digestion, waste anaerobic digestion and distribution of pollutants. The present study is on the basis of comparing economic technologies and appropriate economic ways in order to achieve effective environmental technology.

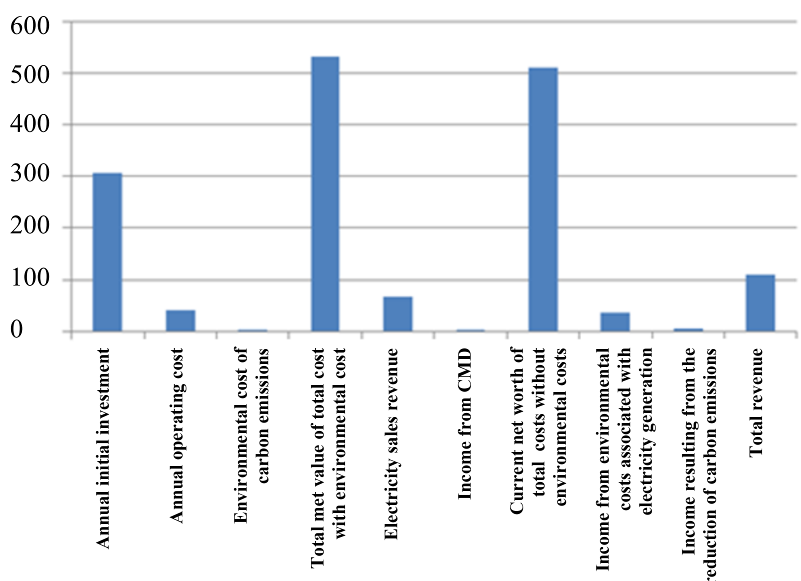

Figure 4. Summary of the gasifier type 1, costs and income

Table 6. Net present value of benefit / cost for incineration technology for MSW, dollar per ton

Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Incinerator	0.28	0.31	0.29	0.27	0.44	0.46

Table 9. Net present value of gasifier costs for MSW, dollar per ton

Scenario / Method	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Type 1	0.64	0.69	0.67	0.62	1.01	1.5
Type 2	0.57	0.60	0.60	0.56	0.91	0.94

Table 7. The summary of costs and revenues of gasifier for MSW, dollar per ton

Gasier type 1		
S. No	Types of costs	$/ton
1	Annual initial investment cost	305.54
2	Annual operating cost	41.40
3	Environmental cost of carbon emissions	4
4	Present net value of total costs with an environmental cost	530.44
5	Present net value of total costs without an environmental cost	510.63
	Types of income	$/ton
6	Earnings from electricity sales	66.78
7	Revenues from reduction of carbon emissions	4.99
8	Income from where environmental costs is avoided (Related to power generation)	36.69
9	Total revenue	108.46

Table 8. The summary of costs and revenues of gasifier for MSW, dollar per ton

Gassier type 2		
S. No	Types of costs	$/ton
1	Annual initial investment cost	271.37
2	Annual operating cost	55.20
3	Environmental cost of carbon emissions	4
4	Present net value of total costs with an environmental cost	564.63
5	Present net value of total costs without an environmental cost	544.82
	Types of income	$/ton
6	Earnings from electricity sales	64.26
7	Revenues from reduction of carbon emissions	4.81
8	Income from where environmental costs is avoided (Related to power generation)	35.31
9	Total revenue	104.38

Finally, the most optimized and economic method is selected at the end of research. Multiple-criteria decision-making tool is on the basis of analytic hierarchy process. The Expert Choice software helps the user in order to create double comparison and even extraction of data. Technologies were investigated from many aspects of view such as engineering economics and economic methods. As a result the most appropriate method has been determined which has less bad effects on the environment (Jacob and William, 2006).

The following two techniques were used in the present study:

Benefit-to-cost ratio: the formulation of benefits to cost ratio is as the following :

$$\frac{B}{C}=\frac{PW}{PW}=\frac{PW_B}{PW_C} \quad (1)$$

$$\frac{B}{C}=\frac{EUA}{EUA}=\frac{EUA_B}{EUA_C} \quad (2)$$

If b/c≥1,the result would be an economic plan, and when b/c≤1, it would be non-economic plan (Park *et al.*, 2007).

Net value

The present method is one of the most important techniques of engineering economics in order to make comparison with other projects (Jouhara *et al.*, 2017). The calculation of value of a fiscal process is as the following: transforming the future values of receipts and payments to the present values of the project.

RESULTS AND DISCUSSION

Financial analysis of technologies

Financial analysis investigates the costs of four

Table 10. Comparison of technology costs

S / t method cost and income	Annual initial invest-ment cost	Annual operating cost	The environ-mental cost of polluting emissions	The net value of all costs with environmental costs	Present net value of total costs without environmental costs	Revenue from electricity sales	Income from environmental avoidance costs	Income from (CMD)	Sales revenue Mt.	Total income with environmental avoidance costs	Total income without environmental pollution avoidance
Waste landfill	10	2	4.13	4.36	19.90	-	8.655	0.48	-	9.13	0.48
Anaerobic digestion	162.5	42.46	4.05	392.90	372.84	52.05	28.15	30.72	30.65	115.72	86.87
Waste incinera-tor	283.41	51.35	5.35	564.34	537.79	31.29	17.20	2.46	-	50.95	33.75
Termiska TPS gasifier	305.54	41.40	4	530.44	510.63	66.78	36.69	4.99	-	108.46	79.77
Columbus Battelle gasifier		271.37	55.20	4	594.63	544.82	64.26	35.31	4.81	104.38	69.07

steps as follows: processing, construction, functioning and closing level. In the present study it is supposed to landfill the waste during 20 years. The initial investment cost is 10 $ and the annual functioning cost is 2 $ (Berlin, 2004). In addition of the mentioned costs, there are other environmental costs such as carbon dioxide release and soluble and also removing the pollutants.

Financial analytic of technologies in the landfill waste

The list of revenues in the landfill waste is as the following: reduction of greenhouse gas emission which is 0.48 $ per tonnage that is equal with 15360 Rials (Berlin, 2004). The amount of environmental costs related to the power generation is 8.655 and per tonnage which is equal with 276960 Rials. The findings of each cost are illustrated in the Table 1 and Figure 1. The net value of benefit to cost is shown in Table 2. The net value of profit to cost in the first four scenarios indicates that it is not possible to run the plan. The mentioned value in the last two scenarios indicates that the plan is acceptable and even profitable.

Financial analysis of anaerobic digestion

The achieved revenues of this study are shown in Table 3 and Figure 2. They are as the following:

- Electricity sale = 52.5 $ per tonnage
- Agrochemical sale = 30.65 $ per tonnage
- Environmental cost related to the power = 28.85 $ per tonnage.

In the case of anaerobic digestion technology, the results of net present value of benefit cost is presented in Table 4 and the net present value of benefit cost at all stages reflects the profitability and acceptability of the project.

Financial analysis of waste incineration technology

In this study, incomes from waste incineration include electricity sales of $ 31.29 per ton, greenhouse gas emission reduction (CDM) of $2.46 per ton of waste, and avoided environmental cost associated with

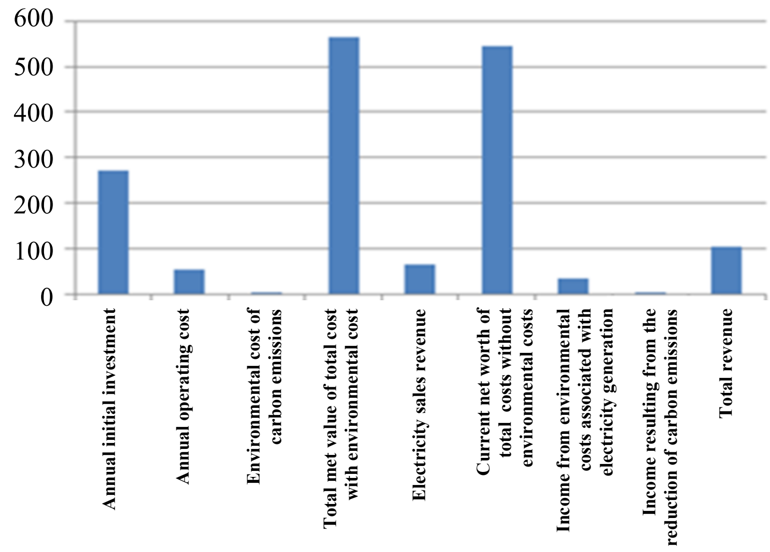

Figure 5. Summary of the gasifier type 2, costs and income

power generation of $ 17.20 per ton of waste that are summarized in Table 5 and Figure 3.

The results of net present value of benefit / cost for incineration technology is as follows (Table 6) which reflects that net present value of benefit / cost for incineration technology show that the project is the ineffectiveness and inapplicable.

Financial analysis of fourth and fifth technology, type one and two of gasification

In this study, incomes derived from gasification includes $ 66.78 and $ 64.26 per ton for electricity sale to type (1) and (2) gasificator, $ 4.99 and $ 4.81 per ton for greenhouse gas emission reduction (CDM) per ton, $ 36.69 and $ 35.31 per ton for avoided environmental cost associated with power generation. The summary of costs and incomes of Gasifier in MSW dollar per ton is showed in Table 7 and Table 8 and Figure 4 and Figure 5.

Based on the results of Table 9, the net present value of benefit/income showed that type (1) gasifier is loss-making in first four scenarios (with and without environmental cost and income from electricity sale by CDM) and it is applicable and profitable in the last two scenarios (with and without environmental cost and income from electricity sale by CDM, avoided environmental cost associated with power generation).

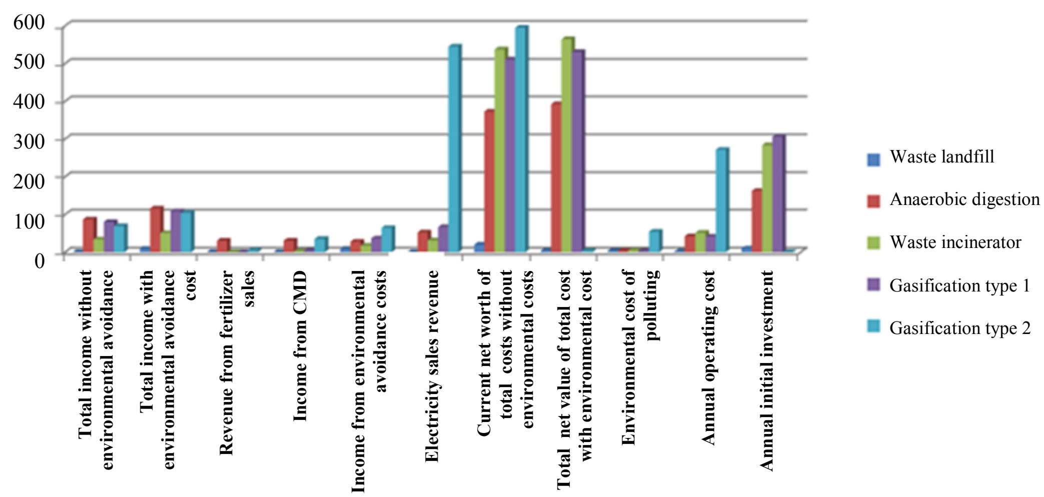

Figure 6. The comparison of technologies cost by dollar per ton, for MSW

Table 11. Net present value of benefit/cost for technologies of MSW, dollar per ton

S. No	Scenario ($/ton) method	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Waste landfill	0	0.11	0.05	0	1.62	2.27
2	Anaerobic digestion	1.10	1.15	1.9	1.4	0.45	1.53
3	Waste incinerator	0.28	0.21	0.49	0.47	0.46	0.46
4	Gasifier Type1	0.64	0.99	0.97	0.62	1.1	1.5
5	Gasifier Type2	0.48	0.61	0.90	0.5	0.91	0.94

It shows that design 1 of type (2) gasifier in all scenarios is loss-making and inapplicable.

Financial comparison of technologies

Based on Table 10 and Figure 6, the minimum annual initial and operational investment cost relates to the waste landfill. In other hand, given that the lowest amount of income is related to the landfill site, so the landfill site has no economic justification. In case of incinerators, given the high operational and investment costs and their low incomes, they are not justifiable economically. Gasificators have high investment and operational costs but high revenues can offset this defect. In anaerobic digestion technology, despite having relatively low investment and operational costs and high incomes, it has a higher economic justification than other technologies. As a result, the most economical energy recovery plan for waste is anaerobic digestion, gasifier type 1, gasifier type 2, garbage burning and eventually waste landfill.

The comparison of net present value of benefit to cost for technologies

Based on Table 11, by the comparison of net present value of benefit to cost for technologies (waste landfill site, anaerobic digestion, waste incineration, gasification) we find that the highest net present value of benefit to cost is for anaerobic digestive technology and the lowest one are related to waste incineration technology and has no difference with gasification. Gasifier type 1 has a slight superiority to gasifier type 2. In the first four scenarios (with and without environmental cost and with CMD), the waste landfill has the lowest net present value of cost/ benefits compared to other technologies, but in the last two scenarios (with and without environmental costs and with CMD and avoided environmental costs associated with electricity production) have the highest net present value of cost/benefit value for waste compared to incineration technology and two gasification

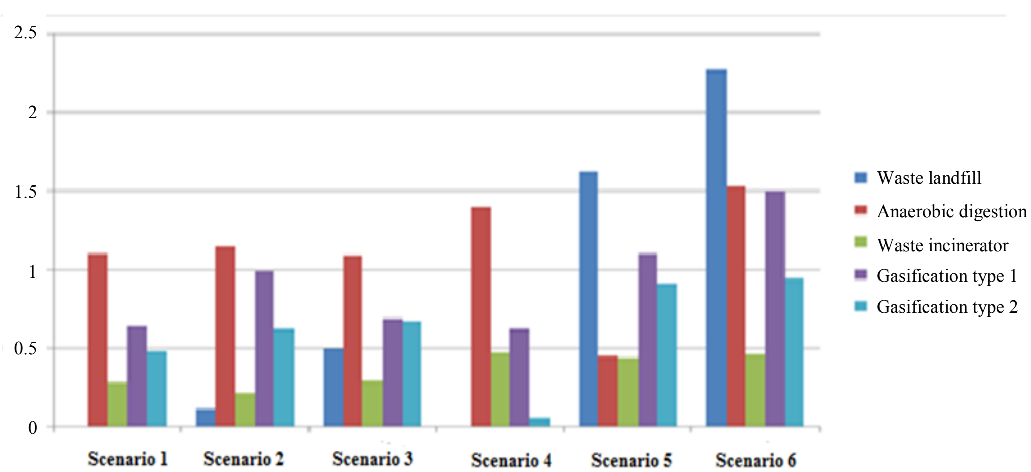

Figure 7. Net present value of benefit/cost for technologies by dollar per ton in MSW

technologies and can be economically justified as an anaerobic digestion technology.

In general, according to Figures 6 and Figure 7 that examined the costs and revenues, despite the fact that anaerobic digestion technology, waste incineration and gasification have high investment and operational costs, but in terms of its revenue from power production, and based on the analysis of benefit-cost for technologies, it is found that these options are more economic than waste landfill center. In all technologies, revenues and costs have been deducted for 20 years, and according to Figures 4 to 7, in all scenarios, except for the sixth scenario, the highest net present value of benefit is related to the cost of anaerobic digestion technology. In the sixth scenario, in the landfill site, if the income from the avoided environmental cost associated with power generation is calculated, it can be economical and affordable.

Environmental comparisons

In the case of environmental comparisons, firstly, by studying the various sources, the impacts that each technology can impose to the environment is identified. Then a list of environmental parameters was prepared for a more accurate review and a comparison process between different technologies. In the next step, with the help of a number of experts, the final list of the main environmental parameters under the effect was determined and was given to a group of experts familiar with the subject for judgment and scoring. Once the parameters are rated between 0 and 10 in relation to their importance compared to each other (in the energy production debate), and once again a number of the effects that each power plant enters on each environmental parameter, and each one that has most points was selected as the most ecological technology. It was also considered in more general terms for each of the two environmental and economic factors. Finally, the scores for different parameters were analyzed using the expert choice 11 software, and one weight was determined for each parameter. Also, the average scores existed for each technology for their effect on each parameter was obtained and finally, a weight was obtained for each option than a given parameter. Subsequently, the weights of each parameter were multiplied by the corresponding option, and finally, the weights were summed in this manner (for each technology) to determine the absolute weight of each technology. In the next step, the results of the economic comparison (in 6 scenarios) are combined with the results of the environmental comparison so that the weight of the environmental factor is multiplied by the weight of the environmental comparison for each power plant and the same has been done for the economic sector. Then the sum of the environmental and

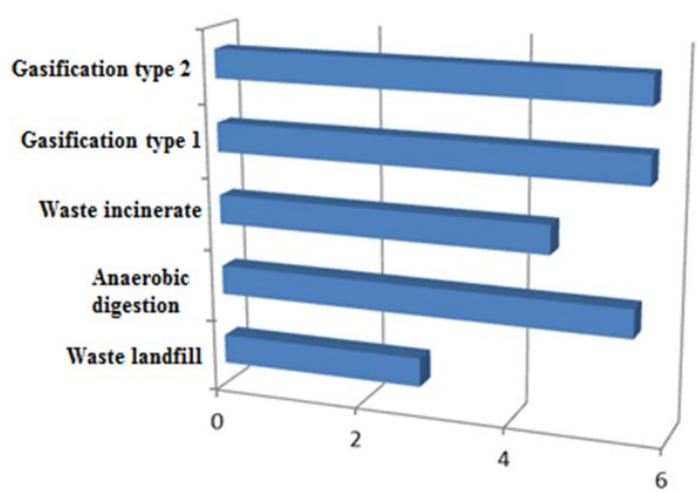

Figure 8. The final weight of the effects of each plant on the environment

Table 12. The final weight of waste landfill technology

S. No	Parameters and options	The weight of each environmental parameter	Waste landfill	The multiplication of parameter weight by options
1	Water quality	0.205	2.66	0.5453
2	Soil quality	0.190	2.33	0.4427
3	Air quality	0.0306	2.66	0.8139
4	Natural sources use (fossil energy)	0.093	2.66	0.2473
5	Occupational safety hazards	0.062	2.33	0.14446
6	Aesthetics	0.026	2.33	0.06058
7	Sound	0.051	3	0.153
8	Implementation ability (technical)	0.065	56	0.3679
9	Total of weights (final weight)	1		2.77528

economic weights of each technology is brought together and a little weight is obtained. The environmental impact of the effects between numbers 1 to 10 is rated for each technology, and according to the results of the tables and charts, and the technology that has less privilege than the rest, it is more destructive. Therefore, the negative effects of the waste landfill are higher than others, and incinerator technology, anaerobic digestion and, ultimately, gaseous preparations are in the next category, and the results are briefly summarized in Table 12 and Table 13 and Figure 8.

Economic and environmental comparisons

In order to determine the best option or options economically and environmentally, economic and environmental comparisons should be combined, for which the weight of the economic factor should be multiplied by the total economic weight of each scenario. Thus, the final weight is obtained for each scenario. In the next step, the environmental factor weight is also reduced to the total environmental weight for each scenario is already calculated, and thus the final weight of the environment is obtained for each scenario. The sum of these two will be the ecological economic weight of any technology and any scenario that has a better result means that it is economically and environmentally appropriate. In order to combine the economic and environmental comparison results, we must first normalize the values obtained from each comparison. The larger the number for the environmental comparison, the better the number is, so the largest number is divided by all the numbers, and the higher the number is, the less the malicious effects are. For the economic comparison, the ratio of the present net profit value to each technology in different scenarios is divided by the largest number of the same group and then multiplied by the weight of the factor of the economy in every normalized numbers. In the final step, after the final normal weight of the environment and the economy is obtained for each technology and scenarios, the final weights of the environmental and economic comparison are combined, and each technology in each scenario with a total score has the same. It means that the economic and environmental point of view is better than the rest of the technology. The results are shown in Table 14 and Figure 9.

Table 13. The final weight of the effects of various technologies on the environment

1	Waste landfill	2.77528
2	Anaerobic digestion	5.54774
3	Incinerator	4.47928
4	Gas maker type 1	5.7039
5	Gas maker type 2	5.7039

Finally, the results of the combination of economic and environmental comparisons are as follows:

- In Scenario 1: The best technology was related to anaerobic digestion (0.98), type 1 gaseous (0.87), type 2 gazebo (0.85), incinerator (0.61) and landfill Waste (34/0)
- In Scenario 2: The best technology was related to anaerobic digestion (0.98), gasifier type 1 (0.88),

Table 14. The final weight of the effects of various technologies on the environment

S. No	Scenario technique ($/ton)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Waste landfill	0.34	0.36	0.35	0.34	0.57	0.64
2	Anaerobic digestion	0.98	0.98	0.98	0.98	0.98	0.88
3	Incinerator	0.61	0.61	0.61	0.61	0.63	0.60
4	Gas maker type 1	0.87	0.88	0.88	0.87	0.90	0.83
5	Gas maker type 2	0.85	0.85	0.86	0.85	0.88	0.82

gasifier type 2 (0.85), waste incinerator (0.61), waste landfill (0.36)

- In Scenario 3: The best technology was related to anaerobic digestion (0.98), gasifier type 1 (0.85), gasifier type 2 (0.86), waste incinerator (0.61), waste landfill (0.35)
- In Scenario 4: The best technology was related to anaerobic digestion (0.888), gasifier type 1 (0.87), gasifier type 2 (0.82), waste incinerator (0.61), waste landfill (0.34)
- In Scenario 5: The best technology was related to anaerobic digestion (0.98), gasifier type 1 (0.90), gasifier type 2 (0.88), waste incinerator (0.63), waste landfill (0.57)
- In Scenario 6: The best technology was related to anaerobic digestion (0.88), gasifier type 1 (0.83), gasifier type 2 (0.82), waste incinerator (0.64), waste landfill (0.60)

Therefore, the best environmental and economic technology in all scenarios is related to anaerobic digestion technology.

CONCLUSION

In this study, in the case of economic comparison, the minimum initial annual investment cost ($ 10 per tonne) and annual operating costs ($ 2 per tonne) are related to the waste disposal center. But on the other hand, since the lowest income ($ 13.9 / t) is related to the waste disposal center, therefore, the waste disposal center has no economic justification. And also, due to the waste incinerators, the cost of investment ($ 234.189) and operating costs ($ 35.50) and their lower incomes ($ 95.50), it can be seen that waste incinerators are not economically justified. The gasifiers have a high investment cost of $ 305,500 for type I and $ 277.700 for type 2 and operational ($ 40.41 for type 1 and $ 20.20 for type 2), but their high income can compensate this defect. In anaerobic digestion technology, despite having the cost of investment ($ 162.5) and operating (42.46) and relatively low and annual income (.117.73), it has a higher economic justification than other technologies. In the case of the present value of net

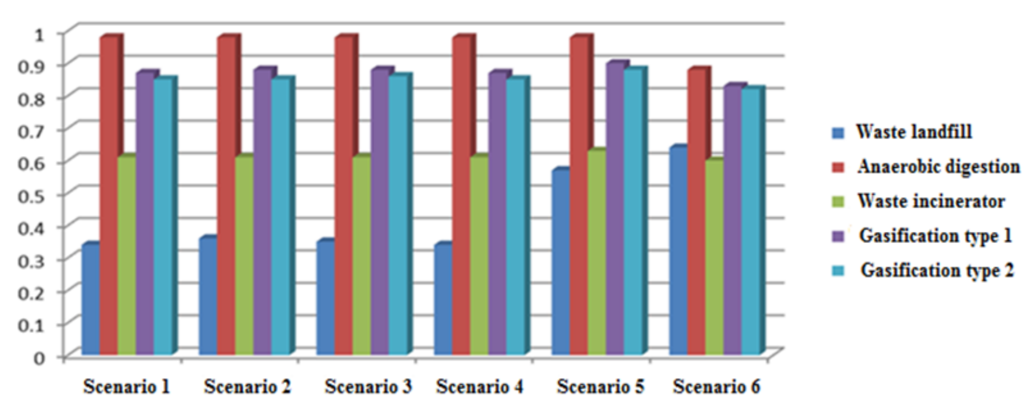

Figure 9. Final weight (environment + economy) for each technology and every scenario

benefit to cost, the highest net present value of cost benefit is related to the first five scenarios of anaerobic digestion technology (scenario 1, 10.1, scenario 2, 15.1, scenario 3, 09.1, scenario 4, 04.1, scenario 5, $ 1.45), and the lowest in all scenarios after waste landfill related to waste technology (scenario 1; 28, scenario 2; 31.0; scenario 3; 0.29, scenario 4; 0.27 scenario; 0.44 scenario; 6.6; $ 0.46), and these do not differ much from the two gasification processes (In gasifier type 1 there is a slight superiority rather type 2 gassing, which is not a very high excellence). Gasifier 1: Scenarios 1 to 6 were 0.64, 0.69, 0.67, 0.62, 01.01, 05.05 and gasifier 2: 0.58, 0.62, 60/0, 0.56, 0.91, 0.94, in the case of landfill in the first four scenarios (with and without environmental cost and with CDM), have the lowest present cost benefit to the cost than other technologies (Scenarios 1 to 4, respectively, 0.11, 0.05, and 0 dollar). However, in the last two scenarios (with and without environmental cost and with CDM and the avoidable environmental cost associated with power generation), the highest net present value of cost benefit is from the waste incineration technology and can have an economic justification just like anaerobic digestion technology (in scenario 5 and 6, respectively, 1.29 and 2.27 dollars per ton of waste). The results of environmental comparisons indicated that the most environmentally friendly technology is related to gasifier type 1, gasifier type 2, anaerobic digestion, waste incineration and waste landfill. Finally, the results of the economic and environmental comparison are combined and the overall result is that the anaerobic digestion in all scenarios is the best technology from the environmental point of view. In the following, 6 scenarios and the amount of cost-benefit ratio that each technology generates in a particular scenario is noted.

- **Scenario 1:** without environmental cost and revenue from electricity sales.
- **Scenario 2:** without environmental cost and revenue from electricity sales and CMD.
- **Scenario 3:** with environmental cost and revenue from electricity sales and CMD.
- **Scenario 4:** with environmental cost and revenue from electricity sales.
- **Scenario 5:** with environmental cost and revenue from electricity sales and CMD and the avoidable environmental cost associated with power generation.
- **Scenario 6:** without environmental cost and revenue from electricity sales and CMD and the avoidable environmental cost associated with power generation.

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