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Waste to Energy: Challenges and Opportunities in Iran

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ABSTRACT

Introduction: Countries around the world are looking for an appropriate, stable, and affordable replacement for the natural energies. Therefore, the waste is considered as an available resource to produce energy, which by controlling, its effects on the environment could be minimized.

Materials and Methods: To conduct this review article, the scientific data related to the topic were gathered from scientific databases such as Google Scholar, PubMed, Elsevier, Scopus, Springer, Magiran, and SID using waste to energy, Biogas, Incinerator, Landfill, and Pyrolysis as the keywords. In addition, 53 articles were used for this research (from 1993 until 2016).

Results: The results indicated that from a technical point of view, according to Iran's current environment and the properties of the produced waste, most methods mentioned in the study are applicable. However, the important issue is to choose the best technologies with the best functionality in Iran, based on the composition of the municipal solid waste, proved technologies, and the municipal solid waste management strategies.

Conclusion: This study recommends construction of incineration plants with an appropriate location for processing municipal, household, and industrial hazardous wastes, as well as energy recovery. In addition, promoting application of household biogas reservoirs in villages and use of pyrolysis for some industries to converse industrial waste into fuel, are further suggested.

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Introduction

One of the most important necessities of life is increasing consumption of energy and its supply for survival and continuation of life. Nowadays, experts believe that the crisis of energy threatens the life of human being [1]. The type of used source of energy is determined by economic, social, environmental and safety considerations [2]. Renewable energy sources and new resources can be applied instead of fossil and ordinary fuels [3]. Renewable sources of energy are used to produce non-renewable energies like electricity. On the one hand, non-renewable sources of energy are about to be finished. Therefore, renewable sources of energy often referred to as alternative sources of energy are required [4]. All of the countries around the globe have prioritized the development of energy sources until 2030, chasing three main goals; 1: global access to the services of new energies 2: increasing the efficiency of energy, 3: developing usage of renewable energies [5]. In the context of renewable powerhouse capacity (except hydroelectric), seven countries in the world have almost 70 % of total global capacity. EU possesses 44 % of the capacity of renewable energies to the end of 2011, and BRICS (Brazil, Russia, India, China, and South Africa) countries have increased their portion of renewable energies by dedicating approximately 26 % of their capacity during [6]. Based on scenarios of international advanced policies and current policies published by committee of renewable energies of European community, in its most optimistic state, half of the world's energy will be supplied from new energies in 2040 [7]. Researchers showed that during the past two decades, many advances have been obtained in the field of renewable energy sources in the world [4]. In 1998, renewable energy sources constituted just 2 % of global consumption of energy consisting of 7exa-joules (1exa-joules = 10^{18} joule) obtained from biological sources and 2 other exa-joules obtained from other renewable energies. However, now, renewable energy sources constitute 14 % of global energy demand[6]. According to renewable energies' scenario in the world, consumption of renewable energies until 2050 reaches up to 318 exa-joules [4]. It is expected that the portion of renewable energies reaches from 30 to 80 % until 2100 [8]. Among the other significant sources of generating renewable energies, we can refer to wastes. Preserving natural resources, improving hygienic and environmental indices, and producing energy as a new source of energy is among the most important advantages of generating energy from wastes [1]. In recent years in Europe, the scale of producing electricity has been tripled and according to the statistics of the International Energy Agency (IEA), the portion of urban waste in supplying primary energy of the world is increasing. Now, 2.1 % of total renewable energies are obtained from wastes, which is equal to 22.16 million tons of crude oil [9]. In most of the villages of India and China, methane gas is used for cooking and heating and china, having over 7 million of biogas equipments, takes the first rank in methane gas consumption in the world. In European countries such as Sweden, the method of generating energy from biogas production has received a great welcome [10]. Sweden is one of the countries with widely use of biogas obtained from urban and rural wastes in the transportation industry, it is predicted that up to 2050, 40 % of Sweden's transportation industry demands will be obtained through biogas [11]. However, in Iran due to the existence of natural gas resources in oil and gas fields, natural gas is more available to populate. But by the growth of population and increased consumption of these resources, it is necessary to compensate the decreasing storage of natural resources by using different methods like generating energy from urban waste [11, 12]. Figure 1, illustrates the general diagram of management methods of converting waste into energy.

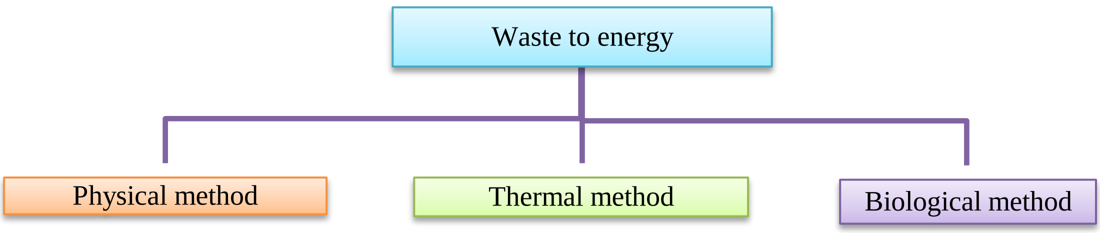

Figure 1: Schematic diagram of waste to energy management methods[13]

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Different technologies are used to extract energy from wastes; among the most common ones, we can mention the following methods. These processes are divided into two categories: thermo-chemical and biochemical methods.

Biochemical methods

In these methods, biological resources are used to generate electricity, heat, and fuels, which are applied in the transportation industry. In these technologies, biological materials are products of metabolic actions of living creatures used as fuel due to their high thermal values. Methane, obtained by the anaerobic digestion process, is one of the most important biologic products [14].

Thermal methods

Thermal refinement processes and energy extraction from urban wastes are utilized successfully around the world [15, 16]. These technologies will cause a quick weight (about 70 to 80 %) and volume reduction of waste (80-90 %). Therefore, it will result in reduction of required land areas in landfill centers; this method is suitable for areas facing with a shortage of land area [17, 18]. Figure 2, showing thermal treatment of waste.

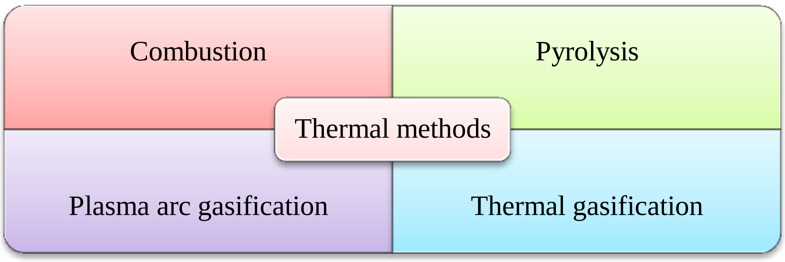

Figure 2: Showing thermal treatment of waste [14]

Materials and Methods

This review study is a result of investigating the articles under the topic of "waste to energy". Data were then collected using the literature, national and international scientific websites such as Google Scholar, PubMed, Elsevier, Scopus, Springer, Magiran, and SID. Further, the key words of Waste to energy, Biogas, Incinerator, Landfill, and Pyrolysis were investigated. Total number of investigated texts and articles were 53 cases obtained from 1993 to 2016.

Results

Biochemical methods

Landfill

Landfill is an engineering method for disposal of solid wastes to preserve the environment. In a landfill, different biological, chemical, and physical processes occur, until the process continues to decompose waste and leads to the production of lechate and gas (lechate is the polluted water emitted from the floor of burial spots). Since active burial spots are mostly anaerobic regarding the microbial activities, these places produce great amount of gas which consists of methane, carbon dioxide, water, and different traceable materials such as ammonia, sulfide, and volatile organic compounds [19].

Landfill is a general source of methane production used to produce electricity [19- 21]. According to statistics of the new energies organization, the maximum potential of electricity production from burial places of cities with a population of more than 250000 was 112 MW in 2008, from landfill powerhouses. However, this rate has been increasing in recent years. In 2011, the United States produced the useful demanding heat of 750000 families synchronized with equal electricity of 62 pj by launching around 567 operational projects of inhabitation of methane produced in landfills. Nowadays, regarding the increasing importance of environmental subjects and implementing methods to decrease greenhouse gases, applying the method of gathering and using landfill gases is increasing in such a way that its application within the past several years increased up to two times in Europe [22]. Among the burial places in Iran, we can refer to hygienic burial centers of Mashhad and Shiraz which produce energy from wastes. In the hygienic burial center of Shiraz, the scale of produced methane and carbon dioxide is respectively 1.5×10^6 and 9.6×10^5 m^3/year, in which each cubic meter of gas extracted from garbage produces an amount of energy equal to 5.22 kWh of electricity. Therefore, this technology will be an effective step in dealing with the huge crisis of urban garbage and decreasing the propagation of environmental pollutants, it also has impressive social and economic effects [20]. Figure 3 compare the predicted production of electricity from landfill gas and other sources in USA, figure 4 diagram of the landfill in Iran, respectively.

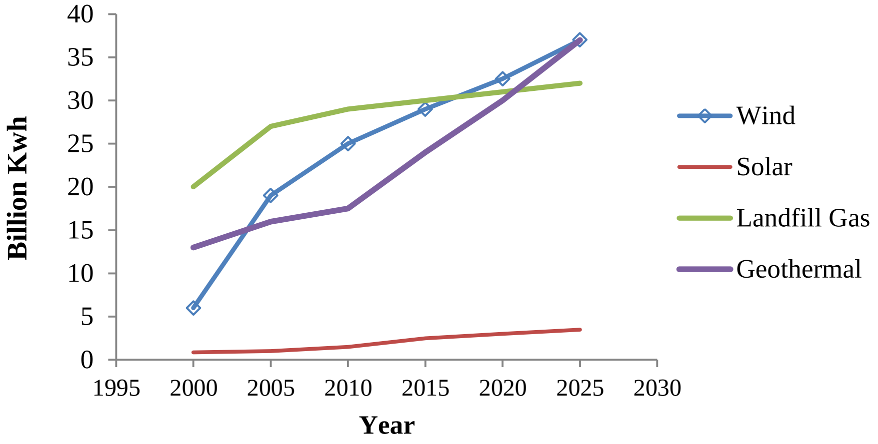

Figure 3: Compare the predicted production of electricity from landfill gas and other sources by the year 2025 in USA[22]

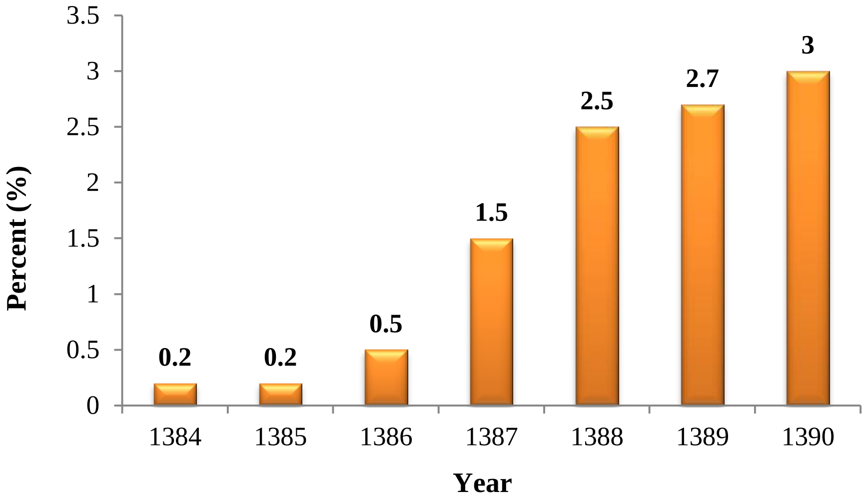

Figure 4: Diagram of the landfill in Iran [6]

Biogas

The decomposition process of biomass resources is conducted by bacteria, anaerobic and produced methane and by products with average thermal value in them. The clearest appearance of this process is in landfills [23]. Recently, reservoir digesters have become very noteworthy. Result of biological decomposition, is a flammable gas called biogas. This gas includes two general components; methane (and a small amount of other

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hydrocarbons) and carbon dioxide along with partial values of impurity like H_2S, vaporized water, and N_2 etc. This mixture is a gas by thermal values of 15-25 mega joules per each cubic meter, from which 1.5-2.2 kWh electricity can be obtained per each cubic meter using existing biogas generators. This gas has a recognizable smell like rotten egg and is lighter than the air. The production mechanism of biogas in the process of anaerobic digestion under the influence of various chemical and biochemical factors is relatively complicated [23].

Nowadays, thermal applications of biogas are improving and developed countries essentially use it in Combined Heat and Power (CHP) powerhouses. In 2010, total obtained thermal energy from biogases in Europe has been around 63 pj. In developing countries, domestic biogas (that it is produced in small and local digesters) is used more for cooking and sometimes for preparing hot water and lightning. China and India have the largest number of these types of domestic digesters among other countries. Nepal and Vietnam each one respectively, with a number of 43 million and 44 million domestic digester in 2011 possess the greatest number of these types of digester, and recently some Asian and African countries have become active in this field [22]. Iran is one of those countries with wide resources to produce biogas. In villages far from cities where there is no possibility of gas delivery, biogas reservoirs can be applied by the supply of animal and human residues. In Iran, production of biogas has an average rate of 16146.35 Mm^3 equal to 333 peta-joules of energy (million giga joules) [24]. In recent years, biogas factory of Mashhad has generated 600 kWh electricity, it is predicted that 192 Mm^3 biogas per each tone of waste will be produced along 13 years [25]. However, in spite of having this potential with relatively simple technology of generators and biogas reactors, there has not been any considerable usage from these resources yet[24]. Most important deterrent factors of biogas usage in Iran are cheap energy, absence of executives and operators, lack of association of people, as well as lack of education and familiarity with this technology [24, 25].

Thermal methods

Gasification

Ignition is carried out in the presence of oxygen less than the value of stoichiometric. The produced gas in this process can be used as a fuel in internal combustion engines, gas turbines, and boilers. Due to high expenses of these technologies and lack of familiarity with them, they have not been welcomed in Iran so far. However, based on the study, which Hooshmand et al., conducted on the analyzing and modeling systems of energy conversion from solid urban wastes, using gasification technology, the results have shown that generating energy from the wastes of Tehran using hybrid gas generator – fuel cell systems is possible. Referring to the economic analysis of the project, the investing capital of projects will return in the period of 9 years in 14 MW powerhouse and 8 years in 20 MW powerhouse [26, 27].

Pyrolysis

In this process, the nature of most of organic wastes converted to liquid, gas, and solid inside a reactor without oxygen and in effect of heat changed due to an external thermal source (900-1700 ^{0}F). Pyrolysis usually is achieved under high pressure and temperature. One of the disadvantages of pyrolysis is high expense of producing and maintaining energy of internal waste in produced coal. In practice, pyrolysis process is used to produce charcoal from wood, flea from coal, and pitch from petrochemical products. Necessary preliminaries in conducting pyrolysis include decomposition of components such as glass, metals, and cardboard, then, materials must be entered into mixer and converted to sufficiently small objects [28, 29]. In general, using Pyrolysis has not been successful so far for urban wastes. The main product of Pyrolysis is carbon monoxide that has high thermal value. Although, attempts have been made since 1960 to eject it from urban wastes, but there were no successful results until now. This technology does not have any record based on application in industrial scale and thus is not recommended for Iran, too [30].

Arc Plasma

Arc Plasma technology had influence in urban wastes management from late 1980s in Europe, but its facility has not been implemented in complete scale for urban wastes [31]. High heat caused by plasma arc leads to fast decomposition of wastes and converts them to gas. In addition, this intensive heat converts non-organic part of garbage to a slag. Slag is a solid glass material that is potentially neutral. Produced gas can be used to generate energy [32]. In Europe or North America, there is no plasma powerhouse in large commercial scale, but some of the plasma systems are tested and used to purify urban wastes. Now, it is under investigation in Canada and Finland [33]. Figure 5 shows the Plasma incineration process and source performance.

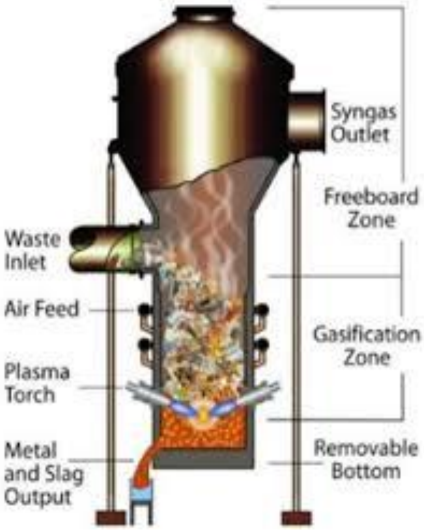

Figure 5: Plasma incineration process and source performance: Westinghouse Plasma Corporation[34]

Among the advantages of Plasma system, some are mentioned here: generating electricity as a source of electric power, designed in a modular and compact format, possibility to use synthesized gases as a clear fuel, and affordable from economical viewpoint [35]. The cost of investing and implementing one unit of incinerator powerhouse with plasma reactor was evaluated as 350000 tons/year that is equal to 80 - 100 million dollars and its production takes 18 months. In comparison with other incinerator factories, this method is more affordable by a system of recycling energy and production of its demanded energy. Due to this reason, all byproducts of this system are used as fuel for turbines or energy and dross for industrial and building usages [31].

Therefore, this system does not produce any pollutant material and causes no increasing in leakage of pollutant materials into the environment, this method does not propagate any bad smell and it does not need large land areas [36]. In addition, this reactor is able to purify many types of wastes including urban, industrial, hospital wastes, etc., except nuclear waste. In this method, there is no need to separate, dry, and chop garbage before and after entrance to the reactor [37]. Recently, the oil industry research center of Iran announced that production of gas from wastes would be performed by using plasma torch technology.

Combustion

Combustion technology has been applied since 100 years ago as a suitable technology to produce energy from urban waste materials. Nowadays, burning technology is used as a common technology of converting wastes to energy. More than 90 % of equipments required for converting wastes to energy are located in Europe, application of these equipments is based on mass burner system, and the biggest device has a capacity of 750000 tons per day [38-40]. Recently, application of mass burner systems has been extended and quality of its ash has improved (less production of incombustible carbon), but the energy revival efficiency scale of this system is just 14 % - 17 % [41, 10]. Capacity of mass burner depends on thermal value of wastes burnt [39]. In recent years in Europe, a high willingness to produce larger incinerator equipments has raised [37-42]. According to recent researches, the equipment of converting waste to energy consist of 100 units, which have been designed based on mass burner system. During the years 2000 to 2011 in Europe, 470 units were established with a capacity equal to 8 million units of garbage per day, this rate would be increased to 550 units to the end of 2016 with the capacity of 97 million tons per day. Among the 450 units used in Europe 420 units were of mass burner type and 30 units of fluidized bed [37].

In the past, mass burning was conducted in order to eliminate waste, but nowadays, electricity and heat production is improving extensively in the world from mass burners. According to the study carried out in 2009 by Haqparast in Tabriz about feasibility of establishing a mass burner powerhouse, the results showed that establishing of mass burner powerhouse is possible in Tabriz regarding its very suitable potential for eliminating waste and production of electricity and thermal energy [43].

Now, in Iran, just in Tehran, facilities have been made to convert wastes to energy which is about to launch. Therefore, there is no complete experience of conducting such project in our country. Regarding the combination of urban productive wastes in our country and lack of execution of recycling programs from source in majority of cities as well as lack of management of dangerous productive wastes, especially in industries, using the waste burner facilities can be regarded as a relatively favorite option to manage these wastes. However, this issue requires observance of positioning standards as well as all environmental, aesthetic, and economic aspects. Furthermore, some equipment should be designed to control these devices' air pollution rates so that the waste burners' effluent observes output standards of air pollution.

Discussion

Solving the problem of waste disposal and producing energy from waste is one of the most challenging problems of the current world. Solving this problem has considerable advantages such as decreasing the emission of greenhouse gases into the environment. Since waste materials have been accepted as a clean source of energy, policies, governmental rules, and new technologies should be considered worldwide to raise the situation of waste-to-energy conversion in the market of renewable energies.

In most of developed countries, especially European countries and Japan, officials have adopted hierarchical approaches in solid waste disposal management. At first, the amount of waste must be decreased, otherwise, recycling or re-use are the other options. Another option is burning or energy recycling. If applying these options were not possible, the last and worst option is burial. Waste burial needs a high volume of land area to be implemented and causes the danger of leakage pollution into air, water, and soil; it also produces less value of energy in comparison with garbage burning. In general, it is supposed that burning has less lateral effects, especially in production of energy from wastes [44-47].

Burning wastes not only reduces the volume of wastes, but also helps production of electricity and/or heat consumption. In burial centers, on the other hand, production of greenhouse gases increases, increasing level of greenhouse gases in turn causes global warming. The increasing level of CO_2 is considered as a warning for the world. Now, coal is responsible for production of 30 % to 40 % of greenhouse gases including CO_2. Further, 98 % of carbon emission into the atmosphere is due to burning of fossil fuels. It is estimated that around 50 % of greenhouse gases is made of CO_2 [9, 22, 37].

Conclusion

Regarding the environmental conditions of Iran and wastes' production characteristics, most of the mentioned methods in the article are applicable and feasible. But an important problem is the choice of applicable technologies for the country, based on the combination of solid urban wastes, proved technologies, and management strategies of solid urban wastes. As far as the major portion of urban wastes in Iran are made of corruptible materials that are moisturized around 60 % has and have low thermal value, it is anticipated that the share of waste burning process is lesser for renewable energies than other processes. Now, in most megacities of Iran, burial of residuals is performed such as burial inside the ground. Therefore, the gas produced in these centers can be prevented by suitable gas emersion management applications to be applied in a proper way and to produce energy, so that after purifying, gas can be delivered to gas delivery networks of Iran [22, 43, 48].

While it helps to solve the urban garbage management problem as well as the many other complications of the future years, burying solid waste materials and demand for alternative energy resources is a common challenge for many of developing countries. Therefore, it is expected that converting energy to residual can present useful experiences for other developing countries like Iran. In addition, authorities and creditors of this section need to focus on modification of hygienic burial locations.

It seems that due to limitation of land area for burial, mass burner is regarded as the final solution and for certain issues; RDF production is suitable and economical for cement industry [30, 49]. Some suggestions are then presented by authors on investigation of waste condition in Iran:

1: Making waste burning factories with suitable positioning to process urban residuals, dangerous domestic and industrial wastes, and revive energy in these factories. 2: Improving usage of domestic biogas sources in the villages of Iran to supply their inhabitants' fuels and using the Pyrolysis process in industries to convert certain kind of industrial waste used as a fuel [50-53]

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Conflict of interest

We have no competing interests.

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