Environmental Energy and Economic Research 2020 4(2): 97-109
DOI 10.22097/eeer.2020.187286.1088

Research Article

Evaluating of Refuse Derived Fuel (RDF) Production from Municipal Solid Waste (Case Study: Qazvin Province)

Fatemeh Aliaghaei [a], Maryam Pazoki [b,•], Forough Farsad [a], Iman Tajfar [b]

[a] Faculty of Natural Resources and Environment, Science and Research Branch, Islamic Azad University, Tehran, Iran
[b] School of Environment, College of Engineering, University of Tehran, Tehran, Iran

Received: 12 July 2019 /Accepted: 28 January 2020

Abstract
Considering population growth in recent decades, and consequently, the increase in waste production in the world, waste management and efforts to reduce their harm to the environment has become an important issue. One of the appropriate ways to manage municipal waste is to generate energy from waste, especially by the RDF production method. On the other hand, to reduce the consumption of fossil fuels in various industries that cause environmental pollution, alternative fuels have become one of the key issues among environmental researchers, for instance providing new fuels with less pollution to cement production plants which use coal as main fuel is increasing. In the present study, the feasibility of producing RDF as an energy supplier in cement factories has been evaluated. For this purpose, in 6 consecutive days, the wastes were collected from Qazvin city and physical and chemical analyses were performed on them. By using the proposed equations, the heat value of the existing waste is calculated. The results show that the heat value of RDF products from wastes is about 9,150 Kj/Kg in summer and 9,400 Kj/Kg in autumn, about thirty percent of coal heat value. Also by removing food wastes and using the five main RDFs material including paper, cardboard, plastics, PET, textiles, and wood, there will be a significant increase of heat value about 110% compared to the presence of food wastes.

Keywords: Municipal Solid Waste, RDF, Heat Value, Cement production plants

Introduction

Municipal Solid Waste (MSW) is an unavoidable by-product of human activities that is increasing dramatically as the population increases (Materazzi et al, 2016; Hoveidi et al, 2013; Pazoki and Dalaei, 2017). On the other hand, the efforts of countries, especially developing countries for economic development, lead to the industrialization of cities and increased consumption of fossil fuels, which in addition to reducing non-renewable resources, increase greenhouse gases and other pollutants (Bosmans et al, 2014). The aim of current European Union waste management guidelines is to implement a waste management hierarchy that includes reduction of production, reuse, recycling, and energy recovery and, ultimately, landfills (Pazoki et al, 2012; Pires and

• Corresponding author E-mail: mpazoki@ut.ac.ir

Martinho, 2019). Due to global warming and fossil fuel reduction, Lots of European countries are trying to achieve the target of Directive 2009/28 / EC (Renewable Energy Directive) by developing energy production from waste. This directive covers producing 20 percent of renewable energies from waste by 2020 (Manyà et al, 2015). To manage this large amount of waste, a plan is needed. One of the factors contributing to the proper implementation of the Waste Management Plan in each country is increasing public awareness and participation. (Abtahi et al, 2015). In recent years, developing countries have begun to improve the waste management system. One of the approaches to the Waste Management Plan is to produce fuel from waste (Rakhshani nasab and Safari, 2015). To develop a plan to use an alternative such as fuel from waste, a flexible and multidimensional approach must be adopted in four areas of the environment, economic, technical and social (Iacovidou et al, 2018). In lots of countries due to the lack of space and leachate production, the waste landfill and greenhouse gas emission have strongly reduced and some rules are being developed (Gallardo et al, 2014; Pazoki et al, 2017).

Since the late 1990s, guidelines have been put in place to reduce landfill final disposal and to increase the use of renewable energy from waste, with countries such as Germany, Austria, Netherland, Denmark and Sweden banning waste disposal (Ham and Lee, 2017). The latest Italian Regulations, to classify the fuels from recycled waste, has offered directives following European standards (EN 15359: 2011). The new law will significantly reduce environmental impacts by reducing landfill waste and increasing recycling and energy production from waste (Bessi et al, 2016). Because of the presence of recyclable materials with high heat value, wastes are considered as a source of renewable energy, but due to their heterogeneous composition, the heat value is low. Paper, cardboard, plastics, and textiles have high energy content, which increases the heat value of wastes. The heat value can also be increased by reducing the moisture content (Ribeiro et al, 2019; Ghasemzade and Pazoki, 2017).

Fuel derived from waste is referred to as waste materials, which are produced as fuel from MSW after various recovery processes. RDF is a waste-derived fuel that results from separation, fragmentation, proper shaping (such as pellet, bricks, fuel rod, etc.) and intelligently formulating components of solid waste in various types of urban, industrial, agricultural is. In general, RDF can be called secondary fuel (Shapouri and Hassanzadeh Moghimi, 2018). Italy's waste production is about 30 million tons of urban waste and 130 million tons of other types of wastes produced annually in the country, this amount has high potential for RDF production which can be achieved with the help of a series of technical standards issued by the European Community, with the aim of facilitating marketing, it can be used as alternative fuels used in traditional fossil fuels, especially in the cement industry (Massarini and Muraro, 2015). Analyzing physical and chemical quality of waste by the municipality in Portugal demonstrated the potential for RDF production from urban waste which its heat content would be raised by adding materials with higher heat properties to them (Brás et al, 2017).

On average about 80 percent of urban wastes in Iran are wet which in many cases can convert into compost. The remaining 20 percent which is dry wastes can be converted into RDF through simple processes and be used as complementary fuel especially in cement factories (Elyasi 2017). The cement industry is one of the most important and applicable industries in the world. Iran produces 2% of global cement share and is the fourth largest cement producing country in the world (Ali, 2014). Comparing the RDF method with other waste disposal methods and their harmful environmental impacts demonstrate that the use of alternative fuels and the reduction of the waste landfill will greatly reduce greenhouse gas emissions and in result will prevent global warming (Di Gianfilippo et al, 2016; Pazoki et al, 2015). In comparison with the waste incinerator, RDF has more importance and capability which in case of moisture reduction of waste and through various processes such as drying, crushing and proper shaping processes, RDF with the heat value of 14000-18600 Kj/Kg, equivalent to 50 percent of coal heat value, which is 32000 Kj/Kg, can be obtained (Badie, 2015).

The quality of the produced RDF is influenced by its heat value. Thus the heat value of RDF produced in the absence of plastic (781 kJ / Nm^3) is slightly higher than the heat value in the presence of plastic (500 kJ / Nm^3) (Kungkajit et al, 2015). On the other hand, the presence of plastic increases the emission of greenhouse gases such as CO_2 (Nutongkaew et al, 2014). Another important factor for increasing the quality and heat value of the fuel derived from the RDF method is to decrease the amount of food waste in solid waste which indicates the necessity and importance of food waste separating from the source (Myrin et al, 2014). One of the most important advantages of using alternative fuels such as RDF is the reduction of SO_2 emissions. Analyzing two types of RDF and adding them with the ratio of 3, 5, 10, 20 and 30 percent to coal and petroleum coke and measuring he heat value of the two material mixture indicates that RDF mixture heat value and coal is more than RDF and petroleum coke and also using RDF ratios in these two types of fuel reduce the SO_2 gas emission (Akdağ et al, 2016). By adding sawdust to RDF product due to carbon existence the moisture would reduce from 22.9 percent to 1.4 percent and the quality would be improved. Also, the heat content will raise from 19.6 Mj/kg to 25.3 Mj/Kg (Białowiec et al, 2017). The torrefaction and carbonization at temperatures of 200 to 400 ° C and a residence time of 15 to 60 minutes increase its heat value. The removal of minerals such as calcium and chlorine increases the quality of this fuel (Nobre et al, 2019). The combination of RDF and tire increases the thermal value without increasing the pollutants (Roknizadeh and Nejati, 2014).

The SRF production process is another method of generating energy from waste similar to RDF. Investigation of the number of minerals in SRF produced from construction waste through mechanical biological treatment showed that the product contains 34% Chlorine, 64% Mercury, 42% Arsenic, 68% Cadmium (Nasrullah et al, 2015). SRF production efficiency from municipal waste is higher than industrial waste and construction waste. In this comparison, the potential sources of contaminants and toxic elements among the waste components were rubber, plastic (hard) and textile (synthetic), and the least amount of contaminants and toxic elements were wood, paper, cardboard, plastic (soft) (Nasrullah et al, 2017). SRF production studies from three waste sources of vehicles, packaging and bulk waste indicated that most of the examined wastes have the limitation of heavy metals. Vehicles wastes are removed to use as recycled solid fuels due to the lower heat value and high amount of heavy metals (Garcés et al, 2016). The mixing of SRF produced with olive tree pruning waste slightly increases the combustion rate but also increases NOx and HCl and dioxin. If the SRF ratio is less than 50% in mixtures, these mixtures should be tested to reduce the emission of these pollutants, or an organochloride compound reduction system may be required (Casado et al, 2016). Analyzing Kerman waste and comparing SRF and RDF demonstrate that considering the amount of produced waste in this province, part of the wastes can be converted to SRF and used as complementary fuel in the cement industry. In this study, the economic value of SRF is estimated higher than RDF (Vahidi et al, 2017).

Another way to generate energy from waste is pyrolysis. In this way, energy can be obtained in a cleaner way than conventional solid waste incineration (Chen et al, 2014). RDF can be used directly or after converting to another type of energy during the pyrolysis process. Pyrolysis of solid waste due to heterogeneous components and inconsistency of its heat content are associated with problems that the use of RDF for pyrolysis solves this problem (Efika et al, 2015). The decomposition and degassing process of RDF in the presence of oxygen and Ni-Ca catalysts with γ-Al2O3 support absorbs and thereby reduces heavy metal emission. On the other hand, the increase in temperature in this process also reduces the emission of heavy metals (Zhou et al, 2016).

Potassium and calcium have the most catalytic effect during the conversion of RDF to gas (pyrolysis) while cyclone and phosphorus prevent it (Aluri et al, 2018).

Material and Methods

In the present study, in order to evaluate the feasibility of using RDF as a complementary energy source for fossil fuels, urban waste of Qazvin province was physically and chemically analyzed and the heat value of RDF was compared with the common fuel used in industry, in the presence and absence of food waste, considering the existence of many industries such as cement factory in this province, economic analysis was carried out in case of using municipal waste as a complementary fuel in the cement production process.

Qazvin province with an area of 155,673 square kilometers is located in the central region of Iran. According to the latest population census, in 2016 the population of the province was 1,273,761 people (Centre, S, 2016). This province produces an average of 500-550 tons of wastes daily and the waste production for each person was reported to be about 450 grams/day. Mohammadabad recycling, processing, engineering, and sanitary landfill complex is 28 kilometers from Qazvin and about 60 kilometers from Abyek cement plant with an area of over 110 hectares. The complex has two separate lines to separate dry waste from wet. In this research, sampling was carried out in two seasons of summer and autumn of 2017 and six consecutive days in half of each season. Considering the arrival of almost all waste from Qazvin province to the disposal site of Mohammad Abad, sampling operation was carried out at this complex. At each sampling, a truck was randomly selected and was discharged in a region away from any other operation and divided into 4 parts, and then one of the four parts was selected and re-divided into four other parts, and a sample of 100 kg was taken, and analyzed by physical and chemical methods (ASTM, 2018).

Figure 1. Map of Iran's national divisions (Taken from the Amazon site)

Result and Discussion

In a physical analysis, the amount of waste material, the percentage by weight of each component and the component density should be measured. At this stage, after the sampling and separation of the components, the mass of each component was measured in kilograms, and then the weight percentage of each waste component was calculated in two seasons, the results are given in Figures 2 and 3.

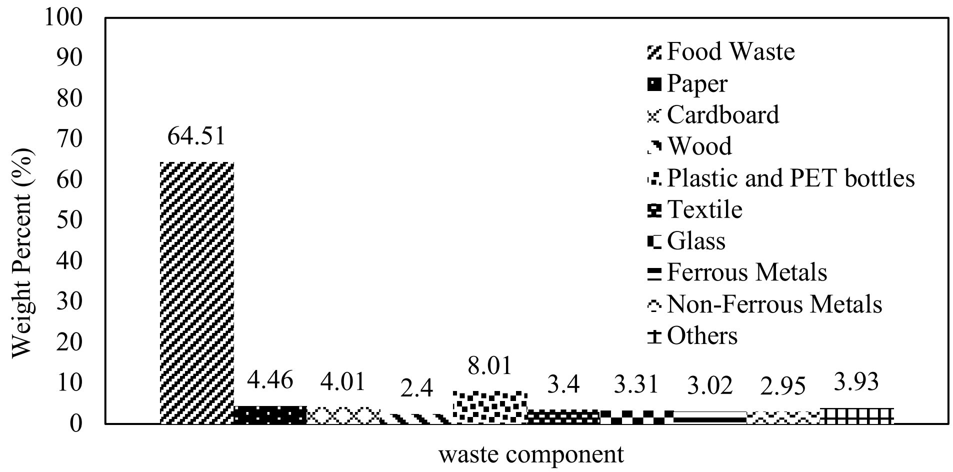

Figure 2. Average frequency chart of waste components for sampling for physical analysis of summer

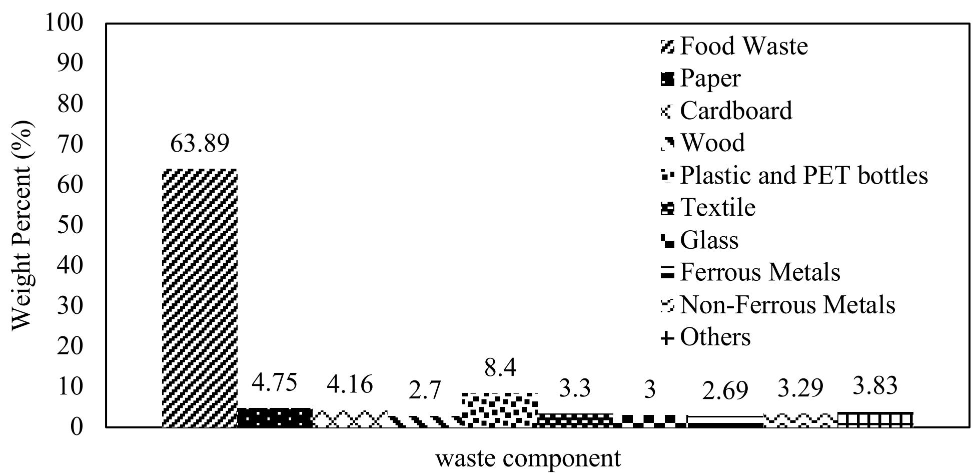

Figure 3. Average distribution chart of waste components for physical analysis of autumn sampling

The two diagrams of Figures 2 and 3 show that there is a significant difference between the food waste and other waste components, and about 80% of the waste are organic materials and 20% are the minerals. About 62% of the wastes are wet and less than 40% are dry type. On the other hand, about 25% of the wastes are from flammable materials, including paper, cardboard, plastic, PET and wood, which are components, need to be used in the RDF. To determine other physical analysis factors, density, the total sample density was calculated every 6 days in two seasons, the average density of 6 days in summer was 12.9 kg / m^3 and in autumn it was 18.14 kg / m^3.

The chemical analysis includes approximate analysis (moisture content and percentage of ash) and the final analysis (heat value). In the following, we will analyze the method of chemical analysis and its results. To carry out the chemical analysis, 12 samples (with equal weight about 3 kilograms) of mixed 100 kg waste were prepared in summer and autumn and placed in black plastic after being transferred to the laboratory for chemical analysis. To determine the changes in moisture content in different days of sampling, 3 kg of total waste was selected and after separation, 2 samples were weighed for measuring the moisture content for each component. To measure the moisture content, the wet specimen was placed in an oven for 24 hours at 110 ° C. It should be noted that the moisture content of each 12 days sampling was similar to the same method, and then the average moisture content of 6 days of sampling was calculated in two seasons, the results are given in Table 1.

Table 1. The average moisture content of 6 days of sampling in the summer and autumn

Waste content	Average summer moisture content	Average autumn moisture content
Food waste	70	74
Paper	6.1	7.4
Cardboard	5	6
Wood	8.3	9.3
Plastic and Pet bottles	2	2.6
Textiles	10	13
Glass	2	2.5
Ferrous metals	3	3.5
Non-ferrous metals	3	3.5
Others	1.1	1.6

According to Table 1, the highest average moisture content in both seasons is related to food waste and glass, plastic and ferrous and non-ferrous metals have the lowest moisture content. This shows the need to pay attention to the proper implementation of the separation scheme from source for optimal waste utilization for energy production. It should be noted that the average total moisture content in two seasons is about 46%. In order to measure the percentage of ash, the samples were dried and powdered and placed in a special furnace at 700 ° C. Thus, the percentage of ash components was measured; the results are given in Table 2.

In the final analysis, in order to calculate the heat value of the RDF-converted waste, it is necessary to first determine the percentage of Carbon, Hydrogen, Oxygen, Nitrogen, Sulfur and Ash components of solid waste. For this purpose, after measuring the moisture content of each component, RDF materials, such as paper, cardboard, plastic, PET and wood, as well as food, were dried and powdered and sent to a reliable laboratory, which measured the weight percentage of the elements as shown in Table 2. It should be noted that this device does not measure oxygen content. Therefore, according to the percentage of ash content of the samples and the fraction of 100 from the total weight of the elements, we can calculate the oxygen content. Another important point is that, due to the lack of significant difference between the results of the laboratory's submission regard to the weight percent of the elements and the percentage of ash percentage, the average 6 days of sampling in summer and autumn were calculated and used.

To calculate the heat value, the Dulong formula is used. For this purpose, it is necessary to measure the weight percentage of the elements and calculate the dry mass of each component of the wastes, the mass of each element, the number of moles by element, the distribution of the weight of each element and the percentage of each element base on the existing relations and then to obtain the heat value with the use of Dulong formula. The chemical formula of the RDF product is determined by the number of moles of each element, which according to the obtained results the chemical RDF formula in summer is C280.9H1249.16O574.99N12.47S and in the autumn season is C58.1H269.79O120.94N2.166S.

Table 2. The average weight percent of the elements and the percentage of ash of each waste component

Waste components	Weight percentage (based on dry weight)											
	Summer						**autumn**					
	*A	S	N	O	H	C	A	S	N	O	H	C
Corruptible material	5	0.8	3.6	36.1	5.4	49	5	3.8	2.4	35.6	6.6	46.6
Paper	7	0.2	0.3	42	6	44.5	6.4	3	3.5	36.7	6.1	44.3
Cardboard	5	0.2	0.3	44.6	5.9	44	5	1.2	1	42.6	5.9	44.3
Wood	29	0.1	0.98	29.1	2.8	38	24	0.3	0.5	23.6	1.6	50
Plastic and PET	10	0.01	2	21.9	7.2	58.8	10	1	1	22.8	6.2	59
Textiles	7.4	0.15	4.6	31.2	6.6	50	2.5	0.15	4.6	31.2	6.6	55

* Ash

Heat value was obtained according to the relations 1, 2 and 3 and based on BTU/IB, which is the British unit for heat, and was multiplied by 2.326 in order to convert to Kj/Kg unit (Nithikul, 2007).

$$Heat\ value\ =\ 145C\ +\ 610\left(H-\frac{1}{80}\right)+10N+40S. \quad (1)$$

$$Heat\ value\ of\ dry\ material = heat\ value\ \times (\frac{100}{100-moisture\ percentage}) \quad (2)$$

$$Heat\ value\ of\ dry\ material\ without\ ash = heat\ value \times \left(\frac{100}{100-moisture\ percentage-ash\ percentage}\right) \quad (3)$$

Table 3. Calculation of total heat value in two seasons

Heat value (Kj/Kg)	**Summer**		**Autumn**	
	*The first scenario	**The second scenario	The first scenario	The second scenario
Normal	9158	20681	9413	21260
Dry material	38016	85851	39074	88254
Dry material without ash	59708	134838	61372	138612

*heat value with the presence of food waste

**heat value without the presence of food waste

In this study, the heat value of the RDF product was calculated once with the presence of food waste and again without its presence, which, as shown in Table 3, significantly the value of heat energy increased by removing food waste. This increase can be attributed to the removal of moisture as a dimming heat value in the waste. Therefore, separation from the source, particularly the separation of food waste in order to increase the heat value of the waste is important.

Economic analysis

About 550 tons of municipal waste is produced daily in Qazvin province. According to the results of this research, 25% of that can be converted to RDF. In other words, about 50,187 tons of RDF can be produced annually from this amount of waste. In cement factories, RDF can be used in both burner and Calciner parts. The use of RDF in the burner part requires a higher cost, because it requires the production of RDF with a very high quality and smaller than 45 mm and also, using a device called the multi-burner (with three ducts for Natural Gas, Mazut and RDF) but there is no need for this equipment in the case of using RDF in Calciner. On the other hand, RDFs can be used with lower quality and lower cost of production and up to 80-100 mm in size. It should be noted that in the factory, there is a need for a place for RDF drainage, a device like a normal band or elevators, which, at a height of about 23 meters, carries fuel into a Calciner and injects it, and also a reservoir for strategic storage that if there is a problem such as repairs or delays in the delivery of complementary fuel to the plant. According to estimations, the initial capital (setting up the production line, personnel salaries, the cost of energy consumption including water, electricity, Natural Gas, as well as the cost of depreciation of equipment) for the production of RDF, as well as the cost of using the cement plant (transmission, equipment and RDF purchase, other unforeseen costs), is estimated between 952,381- 1,071,429 Dollars*. Due to the existence of Mohammad Abad waste processing site, this cost will be much lower in Qazvin province, this cost will be much lower in Qazvin province, as described in Table 5.

Generally, the clinker production capacity in Iran's cement factories is 3,300 tons/ day, with an annual consumption of about 100-110 million cubic meters (equivalent to 80,000-88,000 tons†) of Natural Gas. According to the price for each cubic meter of Natural Gas, approved by the Ministry of Energy (0.028 Dollar), the average fuel cost will be 3,080,000 Dollars per year. The heat value of the Natural Gas is about 8,600 kcal / m^3 (about 36,000 Kj / m^3). Based on the results obtained in the present study, considering the waste composition of the Qazvin province, the heat value of RDF produced from materials usable in the waste, it is about 9,300-kilo joule per kilogram. In order to compare the heat value of RDF with the heat value of Natural Gas, the unit of the two materials should be considered the same. Considering that the weight of each cubic meter of Natural Gas is equal to 0.8 kg, therefore, it can be concluded that the heat value of Natural Gas in kilojoules per kilogram is equal to 45,000.

As regards the heat value of each cubic meter of Natural Gas is about 45,000 Kj / Kg (36,000 Kj / m^3), if RDF is used with a heat value of 9,300 Kj/Kg, 4.8 Kilograms of RDF is required (The heat value of Natural Gas is divided by the heat value of RDF). Considering RDF heat value without any food waste that is about 21,000 Kj/Kg, this number will be 2.1 Kilograms.

The annual fuel consumption at the Abyek cement plant with a production of 8,500 tons of cement per day is 270 million cubic meters per year, which means 10 percent of that is 27 million cubic meters (21,600 tons). According to the above, to replace 10% of Natural Gas with RDF, annually 103,680 tons ($21,600 \times 4.8$) and daily 284 tons RDF is needed, respectively. In the same way, calculations for different percentages of replacement (5, 15 and 20%) for the two RDFs, including the state with the presence of food residues and the state of no food waste, have been taken. According to the amount of Natural Gas consumed in a year which is equal to 270 million cubic meters (216,000 tons), as well as the price approved per cubic meter of Natural Gas (0.028 Dollars), the cost of spent fuel in one year is equal to 7,560,000 Dollars. Now, in order to replace 5, 10, 15 and 20% of the Natural Gas consumed in a year, the cost of saving Dollars will be as described in Table 4. According to analyzes in this research, the heat value of RDF produced from municipal waste in Qazvin is about 9,300 Kj/Kg which is about one-third of coal heat value (about 21,000-31,000 Kj/Kg) and about one-quarter of Natural Gas heat value (about 45000 Kj/Kg). As indicated in Table 4, if you supply 5 percent of the energy consumption of the Abyek cement factory, from RDF, it requires 51,830 tons of RDF annual production with a heat value of 9,300 Kj/Kg and 22,630 tons RDF with heat value about 21,000 Kj/Kg.

* 42000 Rail ≈ 1 US Dollar

2 $1m^3 \approx 0.0008$ ton

Table 4. The annual amount of Natural Gas numerical and currency reserves by replacing with RDF

RDF consumption ratio (%)	Natural Gas consumption ratio (%)	RDF* consumption (ton/year)	RDF** consumption (ton/year)	Natural Gas consumption (ton/ year)	Natural Gas saving (ton/ year)	Natural Gas saving (USD/ year)
0	100	0	0	216,000	0	0
5	95	51,830	22,630	205,200	10,800	378,000
10	90	103,660	45,260	194,400	21,600	756,000
15	85	155,490	67,890	183,600	32,400	1,134,000
20	80	207,320	90,520	172,800	43,200	1,512,000

* RDF with heat value of 93,00 Kj / kg
** RDF with heat value of 21,000 Kj / kg

Table 4 shows the annual numerical and currency reserves of Natural Gas when RDF with different ratios is replaced with Natural Gas. Given the production capability of about 50,187.5 tons of RDF per year from Qazvin urban waste, RDF with a ratio of 5% and a heat value of 9,300 and RDF with a ratio of 10% and heat value of 21,000 KJ / Kg can be used in the cement plant. Therefore, if RDF is produced with higher quality and heat value, less Natural Gas can be used and more currency will be reserved. Table 5 describes the estimated turnover of RDF production to use as a supplementary fuel. To evaluate the plan's economic justification, the net present value (NPV) is calculated which is 576,726 Dollars, considering the positive figure and the IRR of about 98 percent over 15 years; this will be a low-risk investment. It is worth noting that the rate of return (ROI) or profit -to- Cost ratio is at an acceptable level. It should be noted that these calculations are based on a discount rate of 20%.

Table 5. The Financial Process of Producing and Selling RDF as a complementary fuel

Cash Flow	Production Line Startup Cost ($)	Annual Production Cost ($)	Major Maintenance Expenses ($)	Annual Sale ($)	Annual Income ($)
Initial Investment	199,048	-	-	-	-199,048
1	-	65,102	-	264,119	199,017
2	-	65,102	-	264,119	199,017
3	-	65,102	-	264,119	199,017
4	-	65,102	47618	264,119	151,399
5	-	65,102	-	264,119	199,017
6	-	65,102	-	264,119	199,017
7	-	65,102	-	264,119	199,017
8	-	65,102	47618	264,119	151,399
9	-	65,102	-	264,119	199,017
10	-	65,102	-	264,119	199,017
11	-	65,102	-	264,119	199,017
12	-	65,102	47618	264,119	151,399
13	-	65,102	-	264,119	199,017
14	-	65,102	-	264,119	199,017
15	-	65,102	-	264,119	199,017
Total	199,048	976,530	142854	3,961,785	2643,353

NPV (i= 20%): $ 576,726	ROI: 127.5%	PBP: 13 month
IRR: 98%	PI: 1.28	Useful Age of Project: 15 year

With these costs, this process will be economically justified by both the producer and the consumer (cement plant), and if the government subsidizes both producer and consumer the benefit will even be greater for both parties.

Conclusion

In this study, we investigate the quality and quantity of municipal waste in Qazvin province with a population of 127,3761 and with a per capita waste generation of about 450 grams per day, to evaluate the feasibility of using municipal waste for RDF production, as one of the new methods. For this purpose, sampling was done in 12 days in the middle of two months of summer and autumn of 2017 from the waste disposal site of Mohammadabad Qazvin and after physical and chemical analysis, the following results were obtained. Physical analysis results show that there is a significant difference between food waste and other waste components, with about 80% of the wastes are being from organic matter and about 20% from minerals and about 62 percent of the waste is wet and less than 40 percent is dry. On the other hand, about 25 percent of the waste is made up of flammable materials including paper, cardboard, plastic and PET, textiles and wood, which are the components of the RDF. The results of chemical analysis parameters show that the average total moisture content in two seasons is about 46%, which is due to not separating waste from source and high moisture content of food waste. In this study, the heat value was calculated twice and comparison was done.

In the first method, the heat value was calculated in the presence of the food waste and was measured about 9,158 KJ / Kg in summer and 9,413 KJ / Kg in autumn and by eliminating the food waste and 20,681 KJ / Kg in summer and 21,260 KJ / Kg in autumn. This significant difference indicates the importance of waste separating from source for RDF production because the moisture content of the food waste also affects other components and reduces the heat value. The results of the experiments and analyzes carried out indicate almost high-quality waste from Qazvin to produce RDF. In a way that by properly implementing a waste management plan in the province, as well as using the experiences of other leading countries in this field, it is possible to produce a high heat value RDF to replace part of the fuel consumed in the industry. On the other hand, due to the high volume of cement production in Qazvin Abyek cement plant and high consumption of energy, this amount of waste for producing RDF is not enough, which can be used, if agreed, also from other provinces wastes.

In 2017, Vahidi and colleagues investigated the feasibility of using SRF at the Kerman Cement Plant. The results of this study indicated the economic justification of the project. In the present study, for the first time, the waste of Qazvin province was investigated for the feasibility of RDF production as another method of energy extraction from waste for use as supplementary fuel in the industry. Moreover in this study, the heat value of RDF production was calculated in two scenarios, including the presence and absence of food waste, so that its results could be used not only in the cement plant but also in other industries such as waste incinerators and power plants. An economic analysis was then conducted to use it as a supplementary fuel at the Qazvin Abyek cement plant, the results of which indicated that the scheme could have both economic and environmental justifications if the government cooperated to consider fuel subsidies for industries. It is important to note that to increase the rate of RDF replacement; other provinces' wastes can also be used.

Considering the successful experiences of advanced countries in the use of clean alternative fuels such as RDF in the industry which have resulted in reducing fossil fuel consumption and its consequences, this project can be considered as a national plan. In some developed countries, such as Germany and Austria, industries not only pay the cost of replacing fossil fuels with RDF, but they are also provided with RDF for free. Considering the government subsidy for the industries fuel in Iran, by increasing this subsidy for the RDF fuels, there will be less environmental pollution.

References

Abtahi, M., Saeidi, R., Brojrdi, M., Fakhraei, A., Bayat, A., Makari, S. et al. (2015). Evaluation of Knowledge, Education and Public Participation in Waste Management: A Case Study in Tehran. Health Quarterly Journal. Shahid Beheshti University of Medical Sciences. School of Health, 2(3), 7-16.

Akdağ, A.S., Atımtay, A., and Sanin, F.D. (2016). Comparison of fuel value and combustion characteristics of two different RDF samples. Waste Management, 47, 217–224.

Ali. M. (2014). An analysis of the cement industry at a specialized cement industry roundtable. Specialized Journal of Cement Technology, 73, 5-11.

Aluri, S., Syed, A., Flick, D.W., Muzzy, J.D., Sievers, C., and Agrawal, P.K. (2018). Pyrolysis and gasification studies of model refuse derived fuel (RDF) using thermogravimetric analysis. Fuel Processing Technology, (179), 154-166.

ASTM (2018). D5681-18, Standard Terminology for Waste and Waste Management, ASTM International, West Conshohocken, PA.

Badie. M. (2015). Energy from waste. Encyclopedia of Energy.

Bessi, C., Lombardi, L., Meoni, R., Canovai, A. and Cort, A. (2016). Solid recovered fuel: An experiment on classification and potential applications. Waste, (47)B, 184-194.

Białowiec, A., Pulka, J., Stępień, P., Manczarski, P., and Gołaszewski, J. (2017). The RDF/SRF Torre faction: An effect of temperature on characterization of the product – Carbonized Refuse Derived Fuel. Waste Management, (70), 91-100.

Bosmans, A., Dobbelaere, D. D., and Helsen, L. (2014). Pyrolysis characteristics of excavated waste material processed into refuse derived fuel. Fuel, (122), 198–205.

Brás, I., Elisabete, M., Silva, M.E., Lobo, G., AnaCordeiro, A., Miguel Faria, M., and Lemos, L.T. (2017). Refuse Derived Fuel from Municipal Solid Waste rejected fractions- a Case Study. Energy Procedia , (120), 349-356.

Casado, R.R., Rivera, J.A., García, E.B., Cuadrado, R.E., Llorente, M.F., Sevillano, R.B., and Delgado, A.P. (2016). Classification and characterization of SRF produced from different flows of processed MSW in the Navarra region and its co-combustion performance with olive tree pruning residues. Waste Management, (47), 206-216.

Centre, S. (2016). Selected result of the 2016 national population and housing census., Statical center of Iran.

Chen, D., Yin, L., Wang, H., Pinjing He, P. (2014). Pyrolysis technologies for municipal solid waste: A review. Waste Management, (34), 2466–2486.

Di Gianfilippo, M., Costa, G., Pantini, S., Allegrini, E., Lombardi, F., and Astrup, TF. (2016). LCA of management strategies for RDF incineration and gasification bottom ash based on experimental leaching data. Waste Management, (47), 285–98.

Efika, E. C., Onwudili, J.A., and Williams, P.T. (2015). Products from the high temperature pyrolysis of RDF at slow and rapid heating rates. Journal of Analytical and Applied Pyrolysis, (112), 14–22.

Elyasi, M. (2017). Application of waste as fuel in cement plants. Specialized Journal of Cement Technology, 103.

Gallardo, A., Bovea, M.C., Colomer, F.J., and Albarrán, F. (2014). Analysis of refuse-derived fuel from the municipal solid waste reject fraction and its compliance with quality standards. Journal of Cleaner Production, (83), 118-125.

Garcés, D., Díaz, E., Sastre, H., Ordóñez, S., and González-La Fuente, J.M. (2016). Evaluation of the potential of different high calorific waste fractions for the preparation of solid recovered fuels. Waste Management, (47), 164-173.

Ghasemzade, R., and Pazoki, M. (2017). Estimation and modeling of gas emissions in municipal landfill (Case study: Landfill of Jiroft City). Pollution, 3(4), 689–700.

www.amazon.com

Hoveidi, H., Pari, M. A., HosseinVahidi, M. P., and Koulaeian, T. (2013). Industrial waste management with application of RIAM environmental assessment: a case study on toos industrial state, Mashhad. Energy Environ, 4(2), 142–149.

Ham, G.Y., and Lee, D.H. (2017). Consideration of high-efficient Waste-to-Energy with district energy for sustainable solid waste management in Korea. Energy Procedia, (116), 518-526.

Iacovidou, E., Hahladakis, J., Deans, E., Velis, C., and Purnell, Ph. (2018). Technical properties of biomass and solid recovered fuel (SRF) co-fired with coal: Impact on multi-dimensional resource recovery value. Waste Management, 73, 535-545.

Kungkajit, C., Prateepchaikul, G., and Kaosol, T. (2015). Influence of Plastic Waste for Refuse-Derived Fuel on Downdraft Gasification. Energy Procedia, 79, 528-535.

Manyà, J., García, F.G, Ceballos. Azuara, M., Latorre, N., and Royo, C. (2015). Pyrolysis and char reactivity of a poor-quality refuse-derived fuel (RDF) from municipal solid. Fuel Processing Technology, 140, 276–284.

Massarini, P., and Muraro, P. (2015). RDF: from waste to resource – the Italian case. Energy Procedia, 81, 569- 584.

Materazzi, M. Lettieri, P. Taylor, R and Chapman, C. (2016). Performance analysis of RDF gasification in a two stage fluidized bed–plasma process. Waste Management, 47, 256-266.

Myrin, E.S. Persson, P.E. and Jansson, S. (2014). The influence of food waste on dioxin formation during incineration of refuse-derived fuels. Fuel, 132, 165–169.

Nasrullah, M., Vainikka, P., Hannula, J., Hurme, M., and Koskinen, J. (2015). Elemental balance of SRF production process: Solid recovered fuel produced from construction and demolition waste. Fuel, 159, 280-288.

Nasrullaha, M., Hurmea, M., Oinasa, P., Hannulab, J., and Vainikkac, P. (2017). Influence of input waste feedstock on solid recovered fuel production in a mechanical treatment plant. Fuel Processing Technology, 163, 35-44.

Nithikul, J. (2007). Potential of refuse derived fuel production from Bangkok municipal solid waste. Thailand, Asian Institute of Technology. School of Environment, Resources and Development.

Nobre, C., Vilarinho, C. Alves, O., Mendes, B., and Gonçalves, M. (2019). Upgrading of refuse derived fuel through Torre faction and carbonization: Evaluation of RDF char fuel properties. Energy, 181, 66-76.

Nutongkaew, P., Waewsak, J., Chaichana, T., and Gagnon, Y. (2014). Greenhouse Gases Emission of Refuse Derived Fuel-5 Production from Municipal Waste and Palm Kernel. Energy Procedia, 52, 362-370.

Pazoki, M., Abdoli, M., Karbasi, A., Mehrdadi, N., Yaghmaeian, K., and Salajegheh, P. (2012). Removal of nitrogen and phosphorous from municipal landfill leachate through land treatment. World Appl Sci J., 20, 512–519.

Pazoki, M., and Dalaei, P. (2017). The assessment of waste source-separated system in Tehran and comparative analysis between collection systems by RIAM method. International Journal of Environment and Waste Management, 19(3), 233–247.

Pazoki, M., Delarestaghi, R. M., Rezvanian, M. R., Ghasemzade, R., and Dalaei, P. (2015). Gas production potential in the landfill of Tehran by landfill methane outreach program. Jundishapur Journal of Health Sciences, 7(4).

Pazoki, M., Ghasemzade, R., and Ziaee, P. (2017). Simulation of municipal landfill leachate movement in soil by HYDRUS-1D model. Advances in Environmental Technology, 3(3), 177–184.

Pires, A., and Martinho, G. (2019). Waste hierarchy index for circular economy in waste management. Waste Management, 95, 298-305.

Rakhshani nasab. H.R., and Safari, KH. (2015). Strategic planning of waste management in Zahedan by SWOT method. Environmental Science and Technology, 18, 3.

Ribeiro, A. Soares, M. Castro, C. Mota, A. Araújo, J. Vilarinho C, et al. (2019). Waste-to-Energy Technologies Applied for Refuse Derived Fuel (RDF) Valorisation. In: Machado J, Soares F, Veiga G, editors. Innovation, Engineering and Entrepreneurship. Cham: Springer International Publishing, 641–653.

Roknizadeh. J., and Nejati. V. (2014). Technical and economic study of waste fuel and tire Worn in Iranian Industries. Iranian Journal of Energy, 16, 1.

Shapouri, M. and Hassanzadeh Moghimi, O. (2018). RDF Production from Municipal Wastes (Case Study: Babol City). Environ Energy and Economin Research, 2(2), 137–144.

Vahidi, H., Moradi, N., and Abbaslou, H. (2017). Developing of Alternative SRFs in Kerman's Cement Industry by Energy Optimization and Economical Feasibility Approaches. Environmental Energy and Economic Research, 1(3), 259-268.

Zhou, X. Zhang, W.L.P., and Wu, W. (2016). Study on Heavy Metals Conversion Characteristics During Refused Derived Fuel Gasification Process. Procedia Environmental Sciences, 31, 514-519.