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# From Trash to Treasure the Thermochemical Conversion of Garbage into Biofuel

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**Abstract**

In a growing world, where the conventional forms of energy are fast moving towards extinction as well as are contributing generously to global concerns like the greenhouse effect and global warming, the need to innovate and employ alternate or unconventional energy sources has become crucial for the existence of a future. Each month millions of tons of waste are produced. Either they become a part of landfill or are exported to third world countries. This causes huge environmental impact in terms of wildlife, ecosystems and to human health. Keeping this in mind, many new waste treatment plants have come up and have developed new ways to generate energy from landfill waste. In Libya for instance, it can be clearly seen the massive amount of garbage that is produced every day then they burn it in the landfills which causes many significant environmental impacts (i.e. Air pollution). This paper is aimed to convert at least 50% of non-recyclable municipal solid waste (i.e.Garbage) in Ajdabya municipality into clean fuels and renewable chemicals in the short term which is expected to be in 2018, and in the long term by 2020, it is predicted that to convert 80% of the total amount of Garbage that is produced.

*Keywords:* Thermochemical conversion; gasification; mass combustion; biofuels.

## 1. Introduction

Municipal Waste Management (MSWM) is an integral part of the urban environment planning. The properties and the amount of MSW arising from domestic, commercial and industrial activities in a region is not only the result of a growing population and living standards and technological development to increase, but is also the result of the abundance and type of natural resources of the area [1]. Pollution is one of the major problems facing mankind is facing today. This phenomenon occurs in the development of modern man through improvements in industry, agriculture and urban society in connection with the emergence of multiple residues, such as solid, liquid and gas waste. Solid waste, including household, commercial and industrial waste, is the most important type of waste. Solid waste contributes significantly to the pollution of the environment by the main elements pollute (soil, water and air) with the different formulations, concentrations and amounts of materials and components as well as the physical, chemical and possibly antibiotic properties [2]. Wastes from food waste, sewage and animal body parts have been produced to since the creation of life on earth. The amount of this waste has been minimal in the past; Thus, the environment was able to absorb it only cause some environmental problems. At the present time, the waste has to be one of the most pressing social problems; it is a permanent threat to humans and the environment, because some types of waste are toxic and dangerous [3]. Solid waste problems are very critical issues in many urban areas in Libya, including Ajdabya City. The development in this city continue as infrastructure, public service offices, branches and entertainment areas take to increase in number. Moreover, the population of Ajdabya as a result of births and migration of


citizens of small towns and rural areas is growing to grow. Rapid development, industrialization and the growing population contribute to the increase in the amount of waste in the city [4]. The generation of waste is a natural consequence of human life, and the disposal of such waste should be in line with an improved quality of life. As of today, significant new growth opportunities for traditional waste to energy (WTE) plants are grown in developed countries. However, new technologies to convert municipal waste into fuel and electricity, called conversion technologies, develop rapidly. Conversion technologies are needed to due to increase energy problems. These technologies have the potential to perform multiple functions; such waste is stored in landfills, reducing the dependence on fossil fuels and the environmental footprint.

## 2. Overview On The Current Practices, Challenges And Opportunities In Municipal Solid Waste Management (Mswm)

The management of municipal solid waste was carried out in the past six decades in different countries and regions to deal with the specific problems and requirements. A research of Elamrouni [5] et al. (2010) in Benghazi city (Libya), it was concluded that the population growth, rapid urbanization and industrialization resulted in the increase of the problem of solid waste in Benghazi city. Currently, MSW management is one of the leading object and is one of the major concerns of the public as an insufficient waste management can result in health and environmental problems [6] [7] [8]. The main trend in MSWM is to improve waste management practices, allowing them to make more and more sustainable methods. Waste reduction, recycling, source separation, treatment and other methods are used to improve in various ways and systems MSW and divert away in an integrated manner [9] from land sales more and more significant amounts of materials. An integrated waste management (ISWM) system that the reduction, reuse, recycling and disposal of waste materials comprising a major role in the Libyan sustainable development due to its several advantages play:

1. To reduce the depletion of the earth limited natural resources [10] [11] [12] [13].
2. Reduce pollution by discharging untreated waste [14].
3. Indirect energy savings [15].

Currently ISWM is considered to be an optimized management system, where the environmentally and economically best solution is chosen for each case, without regard to the hierarchy of waste [16], and the key to be a successful MSW treatment [17]. The implementation of the ISWM system in countries in general and in Libya in particular the development, however, depends on several important factors such as the economic situation of a country, environmental requirements, the strategies in environmental management, energy policy, economic and technological feasibility, and the formation and environmental awareness [18] [19] [20], some industrialized countries such as Germany, Sweden, the Netherlands, Japan and USA have remarkable results in resource comprehensive utilization and waste management [21] [22] [23]. There have been in the period of 1960-2004 in these countries a lot of changes in the strategies of waste management. A revolutionary change was that the waste management begins with reduction less to begin with and more and recycles reuse. Developed countries like the US, Japan and Western Europe have been trying to produce in a more comprehensive way, in contrast to most developing countries to manage the solid waste. However Libya has yet to take the integrated waste hierarchy. To plan for SWM system is a very complex task, because it is however necessary to examine conflicting goals; In addition, such problems by an intrinsic be uncertain commonly referred to as concerns the estimates of the costs and environmental impact. Such reasons have multiple authors conducted multi-criteria introduce and apply techniques. Such techniques enable the best alternative solution by assessing numerous criteria when choosing [24]. Many approaches to solve environmental problem with multiple criteria, including the Analytic Hierarchy Process [25], and outranking methods [26]. System approach has been to try even when only a few authors, with one or a few aspects of MSWM handling [27] [28] gave an overview of the current waste management practices and its situation in Macao over the past decade. But they pulled conclusion that has been given due to Macao's geographical area and high cost of land, landfill lowest priority incineration for waste disposal and solid waste a top priority on waste management process, although it is much more expensive. One of their suggestions was that for an effective and efficient waste management in Macao, waste minimization be strictly implemented, should the amount of solid waste to reduce. Even for an effective and efficient integrated solid waste management system of the new regulations laying down is also necessary. The arrangements should be notified to the competent authority, to define and implement disposal regulations [29]. A recent study in Sri Lanka from Vidanaarachchi et al performed. (2006) [30] was the problems, issues and challenges of solid waste in the country of southern Providence described confronted. However, they showed that only 24% of households have access to waste collection and that in rural areas it was less than 2%. Significant number of household refuse collection in areas without expecting municipalities to collect their waste. Also, Vidanaarachchi et al. (2006) examined that most locations in the province under capacity are to treat all increased demand. However, they suggested that urgent and immediate improvement of landfills is necessary to meet the current demand for the improvement of waste collection. In view of the foregoing facts, this study is conducted in Ajdabya city. However, it reviewed the current practice of waste management and the way forward and focuses on a number of solid waste management options for many other developing countries, to relevant all non-recyclable municipal waste transform (garbage) in Ajdabya municipality in clean fuels and renewable chemicals, An attempt is further made to explain the challenges and the appropriate way of recycling waste.

## 3. The study area

Ajdabiya is a town in and capital of the Al Wahat District in northeastern Libya. It is located on an arid plain about 6.4 kilometres from the sea and is approximately 850 kilometres from the Libyan capital of Tripoli and 150 kilometres from Libya's second largest city, Benghazi. From 2001 to 2007 it was part of and capital of the Ajdabiya District. The town is divided into three Basic People's Congresses: North Ajdabiya, West Ajdabiya and East Ajdabiya. Ajdabiya is situated in central northern Libya near the Mediterranean Sea coast at the eastern end of the Gulf of Sidra. The city is the site of an important crossroads between the coastal road from Tripoli to Benghazi and inland routes south to the oasis at Jaluand east to Tobruk and the border with Egypt [31].

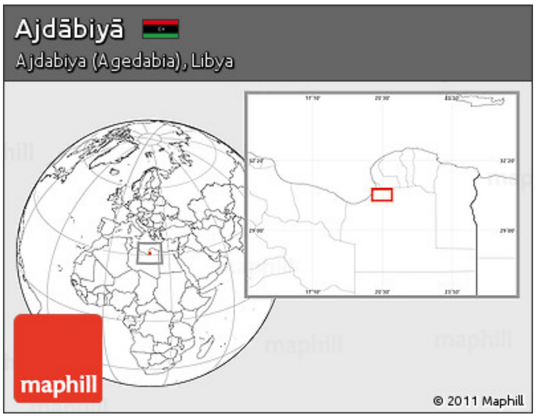


**Figure 3.1:** Location of Ajdabiya city

## 4. Methodology

The present study was conducted through various field visits to several neighborhoods and areas within the city of Ajdabya as well as its neighboring regions. The methods of waste collection and the suitable process to convert municipal solid waste (i.e. Garbage) in Ajdabya municipality into clean fuels and renewable chemicals were examined, and interviews with relevant authorities, including the Environment Public Authority and the Public Service Company of Ajdabya, were conducted in order to assess the current situation and obtain relevant data from pertinent sources. Because some uniform data are missing in various cases, several generalizations have to be made in the process of data analysis. The results from quantitative analyses of the data are given in tables.

## 5. Results and discussion

### 5.1. Solid waste generation and its characteristics

The Minister of Health and Environment of the City Ajdabya, by the corporation of General Services is responsible for the municipal solid waste management, while the cleaning department is responsible for dealing with this waste. The division is responsible for the clean-up of the entire city, including streets, public squares and gardens, among others, and the transfer of waste on the premises, in north western Ajdabya City. The amount of waste generated, which must be disposed in Ajdabya city has increased as a result of insufficient investment in the collection, transportation and treatment plants. These problems are complicated by the political,


economic and social factors in the city. The average production in Ajdabya is about 0.70 to 0.95 kg per person per day, which is almost equal to the national average (1.1 kg per person per day)[31].

### 5.2. Analysis procedure

The flow chart in Figure (5.1), shows the method of MSW generation and management chain of city waste. Also, the flow chart showed the procedure from the MSW analysis to the energy analysis. Showed It is clear from the scheme that it is necessary to know the average Ajdabya‘s MSW components after another distinction the efficiency of waste separation to learn as a group. Moreover, these components are required to investigate the thermochemical conversion process of MSW, for the reason that it is used as an input to this process.

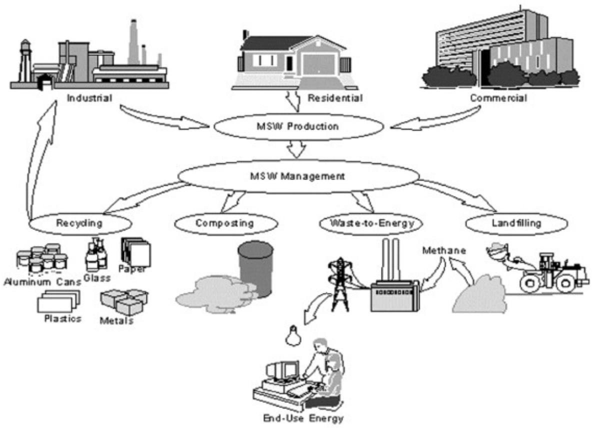


**Figure 5.1:** MSW generationand management chain [7].

#### 5.2.1. MSW analysis

Ajdabya‘s MSW analysis includes data from households, hotels and restaurants, as well as waste, industrial waste. The data were collected by Libyan authorities Statistics Office (LASO) 2006 surveys. The waste from commercial and industrial streams was obtained in comparable countries, like Bani Walid city (Libya), Tripoli City (Libya), Penang (Malaysia), Tehran (Iran), Santiago with literature data on the composition of the same currents determined de Cuba (Cuba ), Beijing and Shenzhen (China) and Gumushane (Turkey) [32]. Coward. Figure 5-2a shows Ajdabya‘s MSW. Moreover, the final composition of MSW determinant about 85% of total waste generated from household solid waste [33]. The largest MSW Group is discovered in the survey was organic materials, as shown in Figure 5-2a. [33]

The forecasted of waste to be generated in the coming years, important to establish the capacity of waste treatment facilities. Because the forecast has no studies progression of Ajdabiya‘s MSW. On the other hand, the quantity of waste generated in 2010 it was 61,870 Tone according to the following calculation:

**(1.1 kg of waste/person/day[31] $\times$ 365 day $\times$ 154,095 inhabitants in Ajdabya in 2010[33] $=$ 61,870,000 kg of waste)**

Therefore, the future MSW generation could be predicted by using that data. Expectation estimations data were taken from the Ajdabya-Libya population (growth rate) [34], the expected population in 2018 will be at 178,328.4 inhabitants and it is forecasted to reach its peak at 184,734 inhabitants in 2020. However, the yearly MSW generation in 2018 and 2020 is estimated to be 71,598.9 and 74,170.7 (Tons of waste/year) respectively.

### 5.3. MSW Conversion Technologies

Biochemical, thermochemical and chemical conversion platforms used to convert MSW feedstocks into clean fuels and renewable chemicals; also, it is possible to convert a variety of waste materials to produce similar products. (See Table 1). All conversion processes require that the MSW to be shredded.

The biochemical and thermochemical platforms each based on different catalytic systems. Biochemical transformation rely on biocatalysts such as enzymes and microbes as well as heat and chemicals to convert biomass into an intermediate sugar substrate, which is then fermented to produce ethanol and other products. Thermochemical conversions rely on heat and / or physical catalysts that convert biomass to a gas or a liquid, depending on the technology, and is then further converted into a fuel, energy, or other chemical products. The pyrolysis and gasification are two thermochemical processes used to convert a variety of biomass feedstocks, including the non-fermentable lignin part of cellulose, give the different products, which result in a variety of fuels, chemicals and energy. Gasification requires that the waste feedstock similar to other biomass to a particle size of 10 mm to 100 mm in diameter and have chipped a lower moisture content or hammer milled so that it may be fed Auger in the gasifier. processing fuels helps to reduce the moisture content of MSW feedstock. Gasification occurs at higher temperatures (1,800$^{o}$F) with oxygen or air



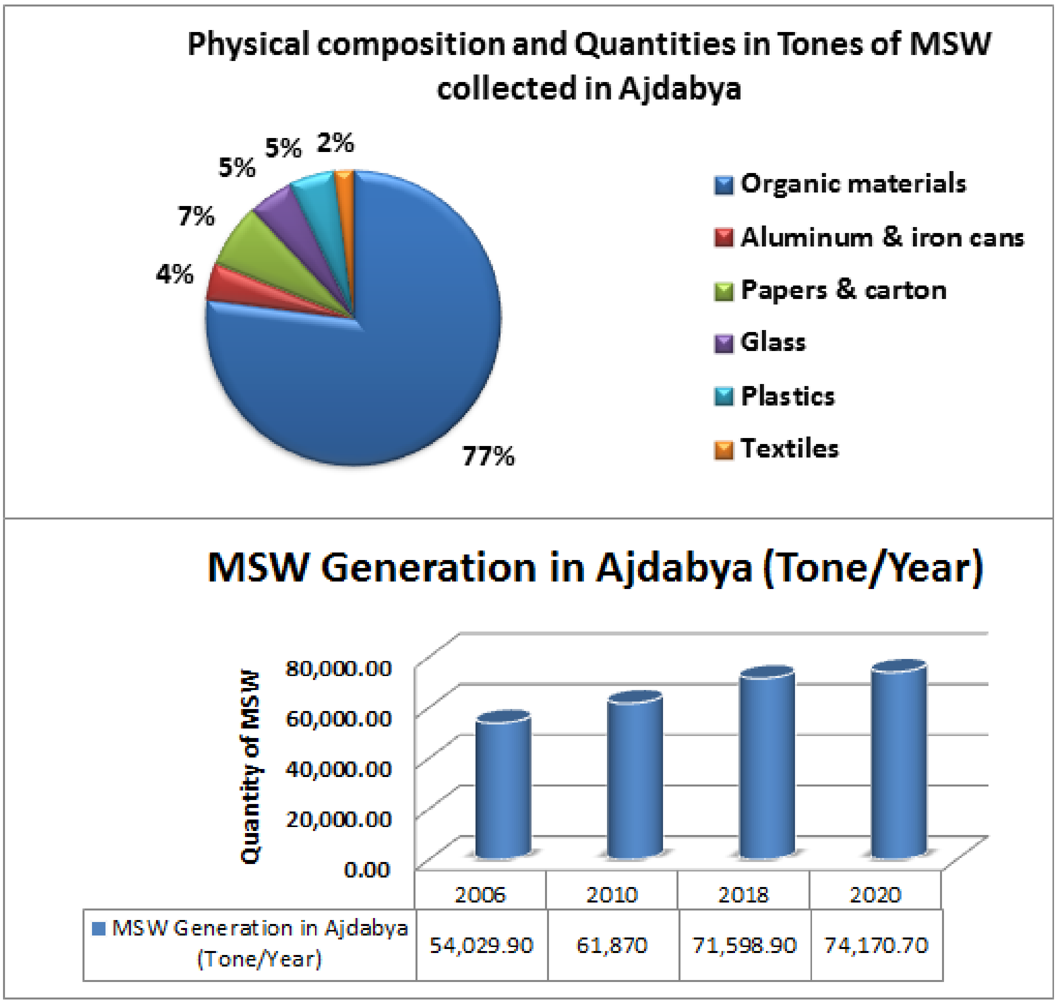


**Figure 5.2:** (a) Physical compositions and quantities in tones of MSW collected in Ajdabya City. [33] (b) MSW Generation in Ajdabya (Tone/Year)

**Table 5.1:** Potential Waste Feedstocks for Biofuels

| Waste Type | Processing Required | Conversion Technologies | Product(s) | Amount of waste Generated in Ajdabya Per Year (Tons) in 2018 |
|---|---|---|---|---|
| Biogenic portion of municipal solid waste, including food wastes | Separation of recyclables (metals, glass, plastics, paper)<br>Shredding of biogenic portion of wastes | Hydrolysis & fermentation | Ethanol, butanol, and microbially- produced alternative fuels | ~ 71,895.9 |
| | | Gasification | Syngas, ethanol, methanol, butanol biodiesel gasoline | |
| | | Pyrolysis | Syngas, biodiesel, gasoline | |


and catalysts. This method leads to a synthesis gas consisting of CO, $H_2$, $CO_2$, $H_2O$, $N_2$ and hydrocarbons, and small amounts of impurities (for example, tar, sulfur, nitrogen oxides, particulate matter and alkali metals). Gas cleaning is necessary to remove them by gas system, followed by hydrogen sulfide ($H_2S$) and the optimization of the $H_2$ / CO ratio to remove fuel synthesis. The composition of the waste may affect the need for syngas cleanup. The syngas which has a low to medium energy content of the fuel undergoes synthesis either by using catalysts or microbes. The choice of catalysts and the $H_2$ / CO ratio, or the choice of the subsequent fermentation of syngas by microbes will determine the products that are manufactured. Diesel and alcohols (including methanol, propanol, butanol and ethanol) can be prepared by gasification, as well as other chemicals. Additionally, syngas can be used for turbine power [34]. Although this paper focuses on MSW, a variety of other types of waste can also use these technologies to be implemented. Manure and sewage sludge are most suitable for anaerobic digestion, given their high moisture content. Dewatering them for use in thermochemical processes, while feasible, would result in high energy inputs and high GHG outputs from pre- treatment. A surprising number of biofuel facilities were either municipalities or waste management companies to use a partnership MSW to produce biofuels:

- Enerkem Mississippi Biofuels in Pontotoc, MS, is a facility that will sort, upstream recycle, and pre- treat MSW, construction and demolition wood, and agricultural and forest residues for thermochemical conversion to a syngas that will further be processed into 20 million gallons ethanol, plus methanol, and plastics, annually. The Enerkem and Three Rivers and Waste Management Authority partnership is constructing the facility using 2009 funding from the U.S. Department of Energy.

- Enerkem has also partnered with the largest ethanol producer in Canada, Greenfield Ethanol, to convert 100,000 metric tons of sorted MSW annually into 10 million gallons of ethanol using gasification, and is expected to be operational sometime in 2011.

- Masada OxyNol plans to hydrolyze and ferment 275,000 tons per year of sorted MSW to produce 9.5 million gallons per year of ethanol at their facility currently under construction in Middletown, NY

- Fulcrum BioEnergy is constructing a 10.5 million gallon per year commercial scale facility (Sierra Biofuels Plant) in Nevada. It plans to thermochemically convert post- recycled MSW to a syngas and further process it into ethanol.

- Agresti Biofuels LLC is planning to co- locate a facility adjacent to the Pike County, KY landfill where it will sort recyclables, cellulosic materials, and metals and use fermentation to convert the cellulose into ethanol.

- BlueFire Ethanol's process is designed to convert MSW wood and other agricultural residues into ethanol, using strong acid hydrolysis and fermentation. Plans include multiple plants with capacities up to 55 million gallons per year with the first facility located in Lancaster, CA.

- Taylor Biomass Energy plans to separate recyclables from 1,000 tons per day of MSW and thermochemically convert the 275 remaining tons to syngas followed by conversion to either ethanol or power.

- Coskata plans to have a 50 million to 100 million gallon ethanol plant up and running using integrated thermochemical and biochemical technology to convert wood chips and expand to MSW, tires, and other waste. Feedstock is first thermochemically converted to syngas and then feeds this syngas to anaerobic microbes to produce ethanol. Coskata has a bench scale pilot in Warrenville, IL and a larger 40,000 gallon per year operational pilot plant in Madison, PA, with plans for a commercial scale 50 Million gallon per year plant in 2011.

- Choren's gasification process followed by a Fischer- Tropsch process produces diesel using a wide variety of feedstocks, including biogenic wastes.

- Biogas Energy Project at the University of California at Davis has successfully converted eight tons of food waste per week in the San Francisco area and is licensed for use by Onsite Power Systems, Inc., in Davis.

### 5.4. Ajdabya's MSW Conversion Options

Currently, there are several viable waste-to-energy options, ranging from low-tech to modern. Mass combustion, the simple process to make garbage burning heat or electricity is used for decades. In

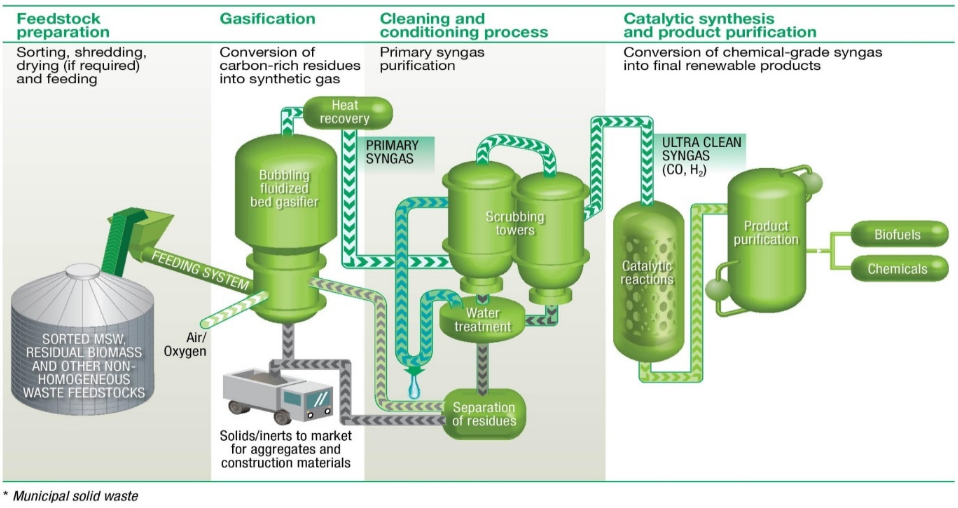


**Figure 5.3:** High level block flow diagram of Gasification process in Enerkem technology. [36]

addition, this technology has to decrease in recent years progressed from the incineration of waste, many of the environmental concerns in the emissions. Unfortunately, the combustion is not always complementary to recycling because they sometimes draw on some of the same materials. It is also very expensive new highly specialized incinerators with the necessary advanced emission control systems of environmental legislation required to build. Therefore, its prospects for the enlarged operation are difficult to predict. Another possible solution for Ajdabya‘s MSW recycling Gasification process, thermally treated in the waste molecularly they break into the building blocks of fuels, which can then be processed into gases, oils or even high-quality liquid fuels that are used could , instead of gasoline. There is a strong desire for alternative energy sources, oil in liquid fuels markets to displace, to make an attractive option gasification. Several companies in the United States, Canada and Europe have recently marketed gasification technologies and more are in the first test phase. However, the incoming material usually must be high-quality homogeneous streams of plastics, it is an unlikely solution (with current technology) for mixed residual stream from recovery come manufacturing and recycling facilities. Enerkem technology can be a model for communities around the world, pulling the circular economy into consideration and seek to manage for sustainable waste. Enerkem, is a technology developer, specializing in the gasification platform: feed preparation, feeding, syngas and syngas Clean-up, catalytic reforming and catalytic synthesis. Enerkem technologies have been tested in the conversion of various wastes to produce products such as municipal solid waste and numerous other carbonaceous waste flows syngas tested, which is then used for the production of heat and / or power, or for the catalytic synthesis of biofuel (methanol and ethanol) and other specialty chemicals, as in Figure 5-3. [36]

Using Enerkem's proprietary technology converts 100,000 tonnes of municipal solid waste into 38 million litres of biofuels and chemicals annually in City of Edmonton, Alberta, Canada [35]. However, according to the above statistics, which is based on Enerkem technology, it is possible to convert nearly 50% of Ajdabya‘s MSW which is predicted to be between (30,000-35,000) Tone per year in 2018 to generate between (10-15) million litres of biofuels and chemicals annually. The main biofuel produced at the plant will be methanol, which can be used as a gasoline additive (Waste-based biofuels can reduce GHG emissions by more than 60% when compared with fossil fuel production and landfill operations). In addition, it is expected to keep up to 80 % of Ajdabya‘s MSW out of landfills by 2020.

## 6. Conclusion and Recommendation

This article describes using local resources from MSW as alternative energy source for city Ajdabya Libya. In summary, the gasification plant gives city of Ajdabya opportunity to save fossil fuel consumption, increase the energy provided, and GHG emissions mitigation. The following recommendations are thus established for the development and implementation of effective and efficient waste management and planning program in Ajdabya municipality.

1. The administration should focus on the improvement and development of waste management in Ajdabya and its surroundings on environmental planning.
2. Environmental awareness should be promoted through the use of all types of media.
3. Small factories should be set up to recycle and use solid waste from households.
4. Setting up new advanced energy research facility in order to innovate new technologies in terms of renewable energy.

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