Boukelia and Mecibah *International Journal of Energy and Environmental Engineering* 2012, **3**:17
http://www.journal-ijeee.com/content/3/1/17

International Journal of Energy and Environmental Engineering
a SpringerOpen Journal

REVIEW Open Access

Solid waste as renewable source of energy: current and future possibility in Algeria

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Abstract

Algeria has created a green momentum by launching an ambitious program to develop renewable energies and promote energy efficiency. Solid waste is one of most important sources of biomass potential in Algeria, which can be used as renewable energy sources.

With economic development and the evolution of population, the quantity of solid waste is increasing rapidly in Algeria; according to the National Cadastre for Solid Waste Generation, the overall generation of municipal solid waste was more than 10.3 million tons per year, and the amount of industrial solid waste, including non-hazardous and inert industrial waste was 2,547,000 tons per year, with a stock quantity of 4,483,500 tons. The hazardous waste generated amounts to 325,100 tons per year; the quantities of waste in stock and awaiting a disposal solution amount to 2,008,500 tons. Healthcare waste reaches to 125,000 tons per year.

The management of solid waste and its valorization is based on the understanding of solid waste composition by its categories and physicochemical characteristics. Elimination is the solution applied to 97% of waste produced in Algeria. Wastes are disposed in the following ways: open dumps (57%), burned in the open air in public dumps or municipal uncontrolled ones (30%), and controlled dumps and landfill (10%). On the other side, the quantities destined for recovery are too low: only 2% for recycling and 1% for composting.

Waste to energy is very attractive option for elimination solid waste with energy recovery. In this paper, we give an overview for this technology, including its conversion options and its useful products (such as electricity, heat and transportation fuel), and waste to energy-related environmental issues and its challenges.

Keywords: Algeria, Renewable energies, Solid waste, Physicochemical properties, Waste management, Valorization, Waste to energy

Review

Introduction

In order to use the enormous source of renewable energies, Algeria has created a green momentum by launching an ambitious program to develop renewable energies (RES) and promote energy efficiency. This program leans on a strategy focused on developing and expanding the use of inexhaustible resources, such as solar, biomass, geothermal, wind, and hydropower, energies in order to diversify energy sources and prepares Algeria for tomorrow.

The program consists of installing up to 22,000 MW of power-generating capacity from renewable sources between 2011 and 2030, of which 12,000 MW will be intended to meet the domestic electricity demand and 10,000 MW destined for export [1]. This last option depends on the availability of a demand that is ensured on the long term by reliable partners as well as on attractive external funding. In this program, it is expected that about 40% of electricity produced for domestic consumption will be from renewable energy sources by 2030.

Solid waste is one of most important sources of biomass potential in Algeria, which is a by-product from human activities, and is characterized by the negative impacts that may affect man and the environment when disposed in an inappropriate way without treatment. Due to the continuously increasing amount of solid waste generated, particularly in capitals and major urban centers, the challenge for the governments is to reduce the waste's harmful impacts to both health and the

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environment. This paper is an investigation on the possibility to use solid waste as a source of bioenergy in Algeria.

Country profile

Algeria, situated in the center of North Africa between the 35° to 38° latitude north and 8° to 12° longitude east, has an area of 2,381,741 km^2 [2,3]. In the west, Algeria borders with Morocco, Mauritania, and Occidental Sahara; in the southwest, with Mali; in the east, with Tunisia and Libya; and in the southeast, with Niger (Figure 1). The geographic location of Algeria signifies that it is in a position to play an important strategic role in the implementation of renewable energy technology in the north of Africa.

The climate is transitional between maritime (north) and semi-arid to arid (middle and south). The mean annual precipitation varies from 500 mm (in the north) to 150 mm (in the south). The average annual temperature is around 12°C.

Algeria has a strongly growing population, with 36,275,358 inhabitants in 2011 according to Population Reference Bureau [4]. In the last 25 years, it has almost doubled. Though we notice a slowing down in the 1990s, the last statistics (sizable increase in marriage rate and in fertility rate) indicate that it is a short-term phenomenon, and the population growth is taking a turn towards fast growth. Algeria is characterized by a young and growing population and a fast urbanization. This situation puts certainly a lot of pressure on the energy, food supply, and even on the environment by increasing the generation of waste and residues.

Algeria plays a very important role in the world energy markets, both as a significant hydrocarbon producer and as an exporter, as well as a key participant in the renewable energy market. According to the 2011 BP Statistical Energy Survey, in 2010, Algeria had proved a natural gas reserve of 4.5 trillion m^3 and natural gas production of 80.41 billion m^3 with consumption of 28.87 billion m^3. Algeria had proved an oil reserve of 12.2 billion barrels at the end of 2010 and produced an average of 1,809 thousand barrels of crude oil per day, according to the same survey; Algeria consumed an average of 327.03 thousand barrels a day of oil in 2010 [2,3,5].

Promotion of renewable energies in Algeria

Algeria's location has several advantages for extensive use of most of the RES, in which it has very important potential of renewable energies including thermal solar (169,440 TWh/year), photovoltaic solar (13.9 TWh/year), and wind energy (35 TWh/year).

Solar energy

Fortunately, Algeria has enormous potential of solar energy. More than 2,000,000 km^2 receives a yearly sunshine exposure equivalent to 2,500 KWh/m^2. The mean

Figure 1 Map of Algeria.

yearly sunshine duration varies from a low of 2,650 h on the coastal line to 3,500 h in the south.

In addition, as shown in Table 1, the potential of daily solar energy is important. It varies from a low average of 4.66 kWh/m^2 in the north to a mean value of 7.26 kWh/m^2 in the south.

Photovoltaic solar energy projects in Algeria: With a potential of 13.9 TWh/year, the government plans launching several solar photovoltaic projects with a total capacity of 800 MW by 2020. Other projects with an annual capacity of 200 MW are to be achieved over the 2021 to 2030 period.

Concentrating solar thermal energy: Pilot projects for the construction of two solar power plants with a storage total capacity of about 150 MW each will be launched during the 2011 to 2013 period. These will be in addition to the hybrid power plant (solar-gas) project of Hassi R'Mel which was built for 130 MW of gas and 25 MW of thermal solar energy with the parabola system of the giant mirrors on a surface of approximately 180,000 m^2.

Four solar thermal power plants with a total capacity of about 1,200 MW are to be constructed over the period of 2016 to 2020. The program of 2021to 2030 provides for the installation of an annual capacity of 500 MW until 2023, then 600 MW per year until 2030.

Wind energy

Wind is another renewable source that is very promising with a potential of 35 TWh/year. The wind map of Figure 2, established by the Centre of Renewable Energies Development (CDER) and the Ministry of Energy and Mines (MEM), shows that 50% of the country surface presents a considerable average speed of the wind. The map also shows that the south-western region experiences high wind speeds for a significant fraction of the year. The Algerian RES program plans at first, in the period of 2011 to 2013, the installation of the first wind farm with a power of 10 MW in Adrar. Between 2014 and 2015, two wind farms with a capacity of 20 MW each are to be developed. Studies will be led to detect suitable sites to realize the other projects during the period of 2016 to 2030 for a power of about 1,700 MW.

Geothermal energy

The Algerian potential of geothermal energy is estimated at 460 GWh/year [7]. More than 200 geothermal sources were counted by the CDER [7] and are recorded, of which one-third of the temperatures are superior to 45°C and where the highest temperatures registered are 98°C and 118°C in Hamam El Maskhoutin and Biskra, respectively, situated in the western part of the country. So far, the applications are limited to agricultural (heating of greenhouses, aquaculture), space heating, sanitary, and balneotherapy.

Hydroelectricity

The overall flows falling over the Algerian territory are important and estimated to be 65 billion m^3 but of little benefit to the country due to the following reasons: restrained rainfall days, concentration on limited areas, high evaporation, and quick evacuation to the sea.

Schematically, the surface resources decrease from the North to the South. Currently, the evaluated useful and renewable energies are about 25 billion cubic meters, of which approximately two-thirds is for the surface resources. Hydraulic electricity represented, with 265GWh in 2003, barely 1% of the total electricity production.

Biomass potential

The biomass potentially offers great promises with a bearing of 3.7 millions of tons of oil equivalent (TEP) coming from forests and 1.33 million of TEP per year coming from agricultural and urban wastes; however, this potential is not enhanced and consumed yet [2,6].

Regulations from the MEM which supports the use of biomass from energy crops rapidly caused an increase consumption of biomass, and in the interest in connecting the agriculture and energy sectors, this is seen as a first step in stimulating the use of biomass in Algeria much faster.

Solid waste generation in Algeria

In this paper, classifications of solid wastes have been proposed according to its origin into three types: municipal solid waste (MSW), industrial solid waste (ISW), and healthcare solid waste (HW).

Table 1 Regional daily solar energy and sunshine duration in Algeria [3]

Parameters	Region		
	Coastal line	High plateaux	Sahara
Area (km^2)	95,271	238,174	2,048,296
Mean daily sunshine duration (h)	7.26	8.22	9.59
Solar daily energy density (kWh/m2)	4.66	5.21	7.26
Potential daily energy (10^{12} Wh)	443.96	1,240.89	14,870.63

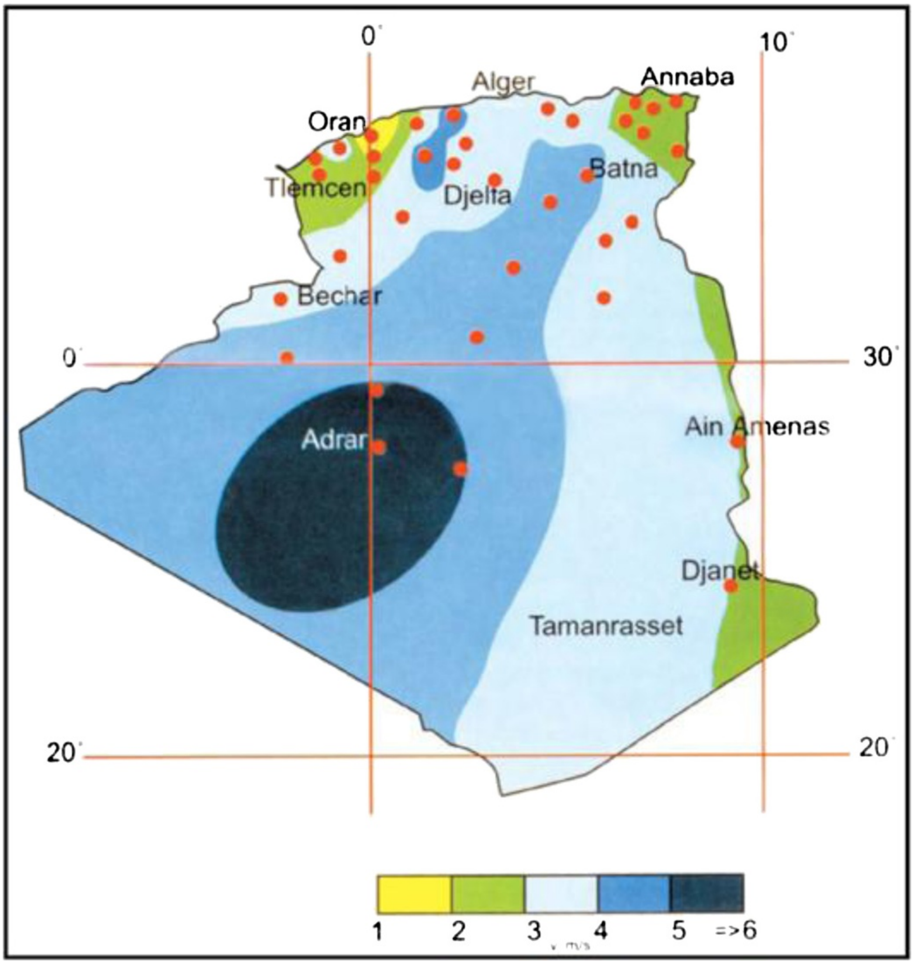

Figure 2 Wind chart of Algeria.

According to the National Cadastre for Generation of Solid Waste in Algeria, the quantity of MSW generated in Algeria is estimated at 10.3 million tons/year (household and similar waste). The overall generation of ISW, including non-hazardous and inert industrial waste, is 2,547,000 tons/year with a stock quantity of 4,483,500 tons. The hazardous waste generated amounts to 325,100 tons/year. The quantities of waste in stock and awaiting a disposal solution amount to 2,008,500 tons. Healthcare waste reaches to 125,000 tons/year according to the same source.

Municipal solid waste

MSW is generally defined as waste collected by municipalities or other local authorities. It includes mainly household (domestic waste), commercial, and institutional wastes (generated from shops and institutions). These wastes are generally in solid or semi-solid form. It can be classified as biodegradable waste that includes food and kitchen waste, green waste, and paper (can also be recycled); recyclable materials such as paper, glass, bottles, cans, metals, certain plastics, etc.; inert waste such as construction and demolition wastes, dirt, rocks, and debris; composite waste which includes waste clothing, tetra packs, and waste plastics such as toys; domestic hazardous waste (also called 'household hazardous waste'); and toxic waste like medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, and shoe polish.

According to the National Waste Agency (AND), Algeria produces 10.3 million tons of MSW each year or 28,219 tons per day, with a collection coverage of 85% in urban areas and 60% in rural areas, and a rate of 0.9 kg/inhabitant/day for urban zones and 0.6 kg/inhabitant/day for rural zones. In the capital (Algiers), the production is close to 1.2 kg/inhabitant/day [8].

The composition of MSW is closely related to the level of economic development and lifestyle of the residents. In different districts of the same city, the composition of

MSW will be different. In general, the composition of MSW in Algeria with six major categories of waste was identified: organic matter, paper-cardboard, plastics, glass, metals, and others (Table 2).

Organic matter was the predominant category and represented 62% of waste collected. The other categories were represented as follows: paper-cardboard (9%), plastic (12%), glass (1%), metals (2%), and others (14%) (Figure 3). Demolition and construction wastes were not taken into account because they are disposed in uncontrolled open-air sites. The high consumption of fruits and vegetables by the city's inhabitants could explain the preponderance of organic matter in Algeria's waste.

Industrial solid waste

According to the National Cadastre for Industrial and Special Wastes prepared in 2007, the overall generation of industrial waste, including non-hazardous and inert industrial waste, is 2,547,000 tons per year with a stock quantity of 4,483,500 tons. This type of waste is generated from the following:

- steel, metallurgical, mechanical, and electrical industries, which are the predominant sectors (50%);
- building materials, ceramics, and glass industries (50%);
- chemicals, rubber, and plastic industries (2%);
- food processing, tobacco, and match industries (29%);
- Textiles, hosiery, and confection industries (10%);
- leather and shoes industries (1%); and
- wood, paper, printing industries (3%).

The hazardous waste which includes waste oil, waste solvents, ash, cinder, and other wastes with hazardous nature (such as flammability, explosiveness, and causticity) generated amounts to 325,100 tons/year. The quantities of waste in stock and awaiting a disposal solution amount to 2,008,500 tons, which are generated by four principal sectors: hydrocarbons (34%), chemistry, rubber and plastic (23%), metallurgy (16%), and mines (13%). Compared to textile (4%) as well as paper and cellulose cement and drifts, food and mechanics produce less than 2%.

Table 3 shows that the eastern regions hold the palm for the production of ISW in Algeria, with the wilayas of Annaba and Skikda which are characterized by a high proportion of waste generated and in stock (the petrochemical, transportation, and hydrocarbons industries of these regions). The western region is in the second position, because the industrial area of Arzew is the largest generator of waste with 65,760 T/year only for its refinery, followed by the industrial area of Ghazaouet with 18,500 T/year. The central region is characterized by the high production of lead waste (manufacture of battery and refinery) [11].

Healthcare waste

These wastes include materials like plastic syringes, animal tissues, bandages, cloths, etc. This type of waste results from the treatment, diagnosis, or immunization of humans and/or animals at hospitals, veterinary and health-related research facilities, and medical laboratories. HW contains infectious waste, toxic chemicals, and heavy metals, and may contain substances that are genotoxic or radioactive. HW reach 125,000 tons/year, of which 53.6% is general waste, 17.6% is infectious waste, 23.2% is toxic waste, and 5.6% is special waste, with waste generation rate 0.7 to 1.22 kg/bed/day, in which 75% to 90% is non-clinical waste and 10% to 25% is clinical waste [13,14].

Waste management situation in Algeria

During the past decades, environmentally sound waste management was recognized by most countries as an issue of major concern. Waste management is an important factor in ensuring both human health and environmental protection [15].

Table 2 Waste composition category [17]

Waste category	Waste components
Organic matter	Waste from foodstuff such as food and vegetable refuse, fruit skin, stem of green, corncob, leaves, grass, and manure
Paper	Paper, paper bags, cardboard, corrugated board, box board, newsprint, magazines, tissue, office paper, and mixed paper (all papers that do not fit into other categories)
Plastic	Any material and products made of plastics such as wrapping film, plastic bag, polythene, plastic bottle, plastic hose, and plastic string
Glass	Any material and products made of glass such as bottles, glassware, light bulb, and ceramics
Metal	Ferrous and non-ferrous metal such as tin can, wire, fence, knife, bottle cover, aluminum can and other aluminum materials, foil, ware and bi-metal
Others	Materials from leather, rubber, textile, wood, and others such yard waste, tires, batteries, large appliances, nappies/sanitary products, medical waste, etc.

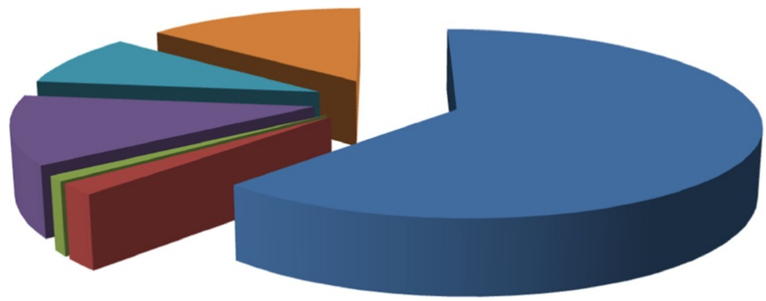

Figure 3 MSW composition in Algeria [10].

Actors of waste management services

Policy and planning: The Ministry of Land Planning and the Environment (MATE) is primarily responsible for national policy environment.

Implementation and operation: AND has the mission to support the local communities in SWM and to promote activities linked to integrated waste management.

Practice of waste management:

1. Municipalities are fully responsibility for the management and control of municipal solid waste.
2. The Ministry of the Interior and Local Communities is for financial and logistical support to the municipalities.

Control and regulatory implementation: The Directorate of Environment of each wilaya (governorate) controls and regulates the implementation of the management services.

Staff training: The National Conservatory for Environmental Training does the staff training.

Policy and planning

Municipal Solid Waste Management National Program (PROGDEM): Launched in 2001, it has already made the development of many SWM projects (municipality master schemes, landfills, etc.) possible.

Industrial and Special Waste Management National Program: This program aims at the control and disposal of special industrial waste and potentially infectious healthcare waste.

Solid waste management

In general, elimination is the solution applied to 97% of waste produced in Algeria. Wastes are disposed in open dumps (57%), burned in the open air in public dumps or municipal uncontrolled ones (30%), and controlled dumps and landfill (10%) (Figure 4). On the other side, the quantities destined for recovery are too low: only 2% for recycling and 1% for composting [8].

Open dump mode: In Algeria, the elimination of household and similar wastes through the implementation of open and uncontrolled dumps is the most common mode used, with a rate of 87%. According to an investigation by the Office of Ministry of Land Planning and the Environment, over 3,130 open dumps have been identified in the country with an area of approximately 4,552.5 ha [8]. The majority of these dumps are characterized by almost similar geographical locations. They are located along rivers, roads or agriculture lands. The other common point is that most of these dumps are almost saturated and cannot practically receive waste.

We can use the open dump of Oued Smar (Figure 5) as an actual example; it is located 13 km from the center

Table 3 Production of hazardous industrial waste in Algeria [12]

The area/production site	Production of HIW		Stock of HIW	
	The quantity (tons/year)	%	The quantity (tons/year)	%
The Eastern region	145,000	45	1,100,800	54.6
The Western region	98,500	30	521,800	25.6
The Central region	77,007	24	378,000	19.5
Southeast and Southwest regions	4,500	1.4	7,900	0.3
Total	325,007	100	2,008,500	100

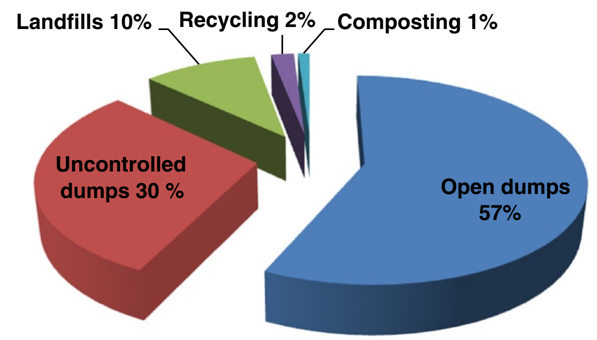

Figure 4 Methods of waste disposal in Algeria.

of Algiers and was established in 1978 on an initial area of 10 ha. It now covers 32 ha and receives more than 700 trucks arriving from 56 municipalities, or 2,200 tons/day of MSW and more than 450 tons/day of rubble and fill. Table 4 provides a summary of the amount of waste placed during the period from 1978 to 2007. It went 15,000 tons during the opening year of discharge to more than 350,000 tons at the end of 2007 [8,16].

Landfill mode: Since 2001, the Algerian government has chosen to eliminate the municipal solid waste by landfill technique, which is a waste storage underground. One of the objectives of PROGDEM is to abandon the traditional mode of disposing waste by open dumps. Following the launching of PROGDEM, 65 landfills were recorded during the period from 2001 to 2005; 16 were completed, 28 under construction, and 21 during the study phase. In the end of 2007, this number has increased due to the results of pilot projects including that of Ouled Fayet in Algiers (Figure 6). It increased to 80 projects, 20 completed, 34 under construction, and 26 in study, or 15 new projects. First, the wilayas concerned are Skikda, El-Tarf, Annaba, Guelma, Souk Ahras, Batna, Tebessa, Media, Tizi-Ouzou, Setif, Biskra, Algiers, M'Sila, Ouargla, Blida, Djelfa, Jijel, Bejaia, and Chelf. In 2010, this number increased to 100 landfills, much of which was nearly completed, according to a communication of same source.

The main advantages of this technology are the following:

- a universal solution that provides ultimate waste disposal;
- relatively low cost and easy to implement to other waste management technology; and
- can derive landfill biogas as a byproduct for household and industrial uses.

However, this technology also has several disadvantages such as landfills requiring a large surface area and pollution problems, including ground water pollution, air pollution, and soil contamination.

The landfill of Ouled Fayet is part of the new policy of integrated waste management which included the transformation of some dumps into landfills. It serves over 34 towns of the wilayas of Algiers and Tipaza. The amount of landfill waste is 864 tons/day in 2005 against 72 tons/day when it opened in 2001. Table 5 shows the evolution of the amount of landfill waste since October 22, 2002.

Composting mode: Composting is a biological method for recovering organic material in solid waste. Composting

Figure 5 The open dump of Oued Smar [8].

Table 4 Quantities of waste received by the open dumps of Oued Smar (1978 to 2007) [8]

Year	1978	1980	1985	1990	1995	2000	2005	2007
Quantity (tons)	15,332	21,221	47,826	107,787	242,926	336,439	375,263	375,263

represents only 1% of all waste produced in Algeria. The only experiments are those of the wilayas of Blida, Algiers, Tlemcen, and Tizi-Ouzou. The main benefit of this technology is that it converts decomposable organic materials into organic fertilizers.

We can give the example of composting station in the city of Blida; this station was put into service in 1989 and rehabilitated during the period from 1992 to 1996 and returned to service in 1996. It spreads over an area of 3.7 ha for a nominal capacity of 100 tons per shift for 8 h and for a production of 40 tons of compost.

Recovery and recycling mode: Depending on the services of the MATE, Algeria has the ability to recover an amount of waste estimated at 760,000 tons/year (Table 6), in which paper is the essential part in the possibility of recovery and recycling with a quantity of 385,000 tons/year. There are over 2 million tons of plastic packaging products in Algeria by 192 units, but only 4,000 tons are recovered (0.0002%).

Valorization of MSW

Valorization is the conversion of waste to energy, fuels, and other useful materials with particular focus on environmental indicators and sustainability goals. It is part of the larger endeavor of loop closing.

Physicochemical properties of MSW

Knowledge of the physicochemical parameters of MSW allows the evaluation of the potentially harmful risks of pollution on the environment and human health. Also, it allows the determination of the best ways for the valorization of waste. The most important conditioning parameters for valorization are listed in the following sections [17,18].

Bulk density: An important characteristic of biomass materials is their bulk density or volume. The importance of the bulk density is in relation to transport and storage costs.

Level of moisture: This represents the quantity of water in the MSW.

LCV: This is the total energy content released when the fuel is burnt in air, including the latent heat contained in the water vapor and, therefore, represents the maximum amount of energy potentially recoverable from a given biomass source content, or heat value, released when burnt in air.

Amount of ash: This is the solid residue from the bioconversion in addition to other physicochemical properties such as volatile matter content, C/N ratio, and pH.

From previous studies which were carried out by Tabet [3], Guermoud [19], and Loudjani [9] show the values of physicochemical parameters as shown in Table 7.

Figure 6 Landfill of Ouled Fayet [16].

Table 5 Evolution of the amount of landfill waste at the site of Ouled Fayet [8]

Period	Number of days	Number of trips	Tonnage (tons)
22/10/02 to 18/07/03	270	19,588	86,780
19/07/03 to 31/03/04	257	14,034	54,433
06/05/04 to 31/05/06	756	115,086	583,014
22/08/07 to 31/10/07	71	13,625	42,178

Waste-to-energy conversions

Energy from waste is not a new concept, but it is a field which requires a serious attention. There are various energy conversion technologies available to get energy from solid waste, but the selection is based on the physicochemical properties of the waste, the type and quantity of waste feedstock, and the desired form of energy. Conversion of solid waste to energy is undertaken using three main process technologies: thermochemical, biochemical, and mechanical extraction [20].

Biochemical conversion: Biochemical conversion processes make use of the enzymes of bacteria and other microorganisms to breakdown biomass. Biochemical conversion is one of the few which provide environment friendly direction for obtaining energy fuel from MSW. In most of the cases, microorganisms are used to perform the conversion process: anaerobic digestion and fermentation.

1. Anaerobic digestion is the conversion of organic material directly to a gas, termed biogas, which has a calorific value of around 20 to 25 MJ/Nm^3 with methane content varying between 45% and 75% and the remainder of CO_2 (biomass conversion) with small quantities of other gasses such as hydrogen.

2. Fermentation is used commercially on a large scale in various countries to produce ethanol from sugar crops. This produces diluted alcohols which then are needed to be distilled and, thus, suffers from a lower overall process performance and high plant cost.

Table 6 Recycling capacity

Types of waste	Quantity (tons/year)
Paper	385,000
Plastic	130,000
Metals	100,000
Glass	50,000
Various materials	95,000
Total	760,000

Thermochemical conversion: Thermal conversion is the component of a number of the integrated waste management solutions proposed in the various strategies. Four main conversion technologies have emerged for treating dry and solid waste: combustion (to immediately release its thermal energy), gasification, pyrolysis, and liquefaction (to produce an intermediate liquid or gaseous energy carrier).

1. Combustion is the burning of biomass in air. It is used over a wide range of commercial and industrial combustion plant outputs to convert the chemical energy stored in the solid waste into heat or electricity using various items of process equipment, such as boilers and turbines. It is possible to burn any type of biomass, but in practice, combustion is feasible only for biomass with a moisture content <50%, unless the biomass is pre-dried.
2. Gasification process means treating a carbon-based material with oxygen or steam to produce a gaseous fuel. Gas produced can be cleaned and burned in a gas engine or transformed chemically into methanol that can be used as a synthetic compound.
3. Pyrolysis is the heating of biomass in the absence of oxygen and results to liquid (termed bio-oil or bio-crude), solid, and gaseous fractions in varying yields depending on a range of parameters such as heating rate, temperature level, particle size, and retention time.
4. Liquefaction is the low-temperature cracking of biomass molecules due to high pressure and results in a liquid-diluted fuel. The advantage of this process, employing only low temperatures of around 200°C to 400°C, has to compete with comparably low yields and extensive equipment prerequisites to provide the pressure levels needed (50 to 200 bars).

Mechanical extraction: It can be used to produce oil from the seeds of solid waste. Rapeseed oil can be processed further by reacting it with alcohol using a process termed esterification to obtain biodiesel, for example.

Biogas market options

The kind of energy produced from the biogas depends directly on the needs of the buyer, and there are three different forms: electricity generation, heat and steam generation, and transportation fuel [21].

Electricity generation: This is the most common form of energy produced in facilities constructed today.

1. Combined heat and power (CHP) generation, also known as cogeneration, is an efficient, clean, and reliable approach to generating power and thermal energy from solid waste. By installing a CHP system

Table 7 Physicochemical properties of MSW

Property	Value
pH	6 to 7
Medium bulk density	0.45 to 0.55 tons/m^3
Fraction of waste >40 mm	80% to 90%
Moisture content	50% to 60%
Volatile matter	40% to 60%
Ashes	15% to 40%
C/N	18 to 20
HCV	1,400 to 1,600 kcal/kg

designed to meet the thermal and electrical base loads of a facility, CHP can greatly increase the facility's operational efficiency and decrease energy costs. At the same time, CHP reduces the emission of greenhouse gasses, which contribute to global climate change.

2. Fuel cell technology: Converting biogas to electricity via fuel cell technology offers significant increases in efficiency and, hence, is a highly desirable technology. Some biogas installations do exist, utilizing molten carbonate fuel cell technology; however, it is widely considered that solid oxide fuel cell technology is the most promising future technology due to its much higher power density and its applicability to a wide range of scales.
3. Biogas engines: Biogas can be used as a motive power for the production of electricity using engines. A biogas-fueled engine generator will normally convert 18% to 25% of the biogas to electricity, depending on engine design and load factor.
4. Microgas turbines: Small gas turbines that are specifically designed to use biogas are also available. An advantage to this technology is lower NO_x emissions and lower maintenance costs; however, energy efficiency is less than with IC engines and it costs more.

Heat and steam generation: Producing and selling heat and steam requires the existence of available industrial customers and matching the supply with their needs. It is also possible to use steam at institutional or domestic complexes.

Transportation fuel: Biogas is used as a transportation fuel in a number of countries. It can be upgraded to natural gas quality in order to be used in normal vehicles designed to use natural gas.

Waste-to-energy technology in Algeria

In Algeria, a little interest was given to this technology despite the important resources and the successful applications that have been made by the National Institute of Agronomy (El Harrach) and the CDER through the establishment of two experimental plants in Bechar and Ben Aknoun for the study of biogas production from cow dung. However, we must note the efforts of the Algerian government in these last years to develop this technology by upgrading the landfill of Ouled Fayet which has been put into operation in 2011. The project's main objective is the capture of the landfill's gas which contains 50% of methane (CH_4); the expected amount of emission reduction is 83,000 T equivalent CO_2/year [22].

In addition to biomass, power projects are at the feasibility study stage such as the Sonelgaz's biomass power project in the Oued Smar site, which has an installed capacity of 2 MW that can reach a peak of 6 MW from the discharge of this site, and the energy recovery plant of biogas generated in the landfill of Batna [12].

Waste-to-energy-related environmental issues

Reduction in landfill dumping

Landfills require large amounts of land that could be used for other purposes; incineration of solid waste can generate energy while reducing the volume of waste by up to 90%.

Reduced dependence on fossil fuels

With advanced technologies, waste can be used to generate fuel that does not require mining or drilling for increasingly scarce and expensive non-renewable fossil-fuel resources.

Reduced greenhouse-gas emissions and pollution

Using waste as a feedstock for energy production reduces the pollution caused by burning fossil fuels. While traditional incineration still produces CO_2 and pollutants, advanced methods such as gasification, pyrolysis, and liquefaction, have the potential to provide a double benefit: reduced CO_2 emissions compared with incineration or coal plants, and reduced methane emissions from landfills.

WTE provides clean energy

The WTE technology has significantly advanced with the implementation of the Clean Air Act, dramatically reducing all emissions.

Waste-to-energy challenges

Lack of versatility

Many waste-to-energy technologies are designed to handle only one or a few types of waste (biomass, solid waste or others). However, it is often impossible to fully separate different types of waste or to determine the exact composition of a waste source. For many, waste-to-energy technologies to be successful, they will also have to become more versatile or be supplemented by material handling and sorting systems.

Waste-gas cleanup

The gas generated by processes like pyrolysis and thermal gasification must be cleaned of tars and particulates in order to produce clean and efficient fuel gas.

Conversion efficiency

Some waste-to-energy pilot plants, particularly those using energy-intensive techniques like plasma, have functioned with low efficiency or actually consumed more energy than they were able to produce.

Toxic materials include trace metals such as lead, cadmium and mercury, and trace organics, such as dioxins and furans. Such toxins pose an environmental problem if they are released into the air with plant emissions or if they are dispersed in the soil, allowed to migrate into ground water supplies, and work their way into the food chain. The control of such toxins and air pollution is the key feature of environmental regulations governing MSW-fueled electric generation.

Regulatory hurdles

The regulatory climate for waste-to-energy technologies can be extremely complex. At one end, regulations may prohibit a particular method, typically incineration, due to air-quality concerns, or classify ash byproducts of waste-to-energy technologies as hazardous materials. At the other end, while changes in the power industry have allowed small producers to compete with established power utilities in many areas, the electrical grid is still protected by yet more regulations, presenting obstacles to would-be waste-energy producers.

High capital costs

Waste-to-energy systems are often quite expensive to install. Despite the financial benefits they promise due to reductions in waste and production of energy, assembling the financing packages for installations is a major hurdle, particularly for new technologies that are not widely established in the market.

Conclusion

This paper gives an overview on the Algerian potential of solid waste including MSW, ISW, and HW as biomass sources. The management of solid waste (MSW) and valorization is based on the understanding of MSW composition by its categories and physicochemical characteristics.

Energy from waste is not a new concept, but it is a field which requires a serious attention. There are various energy conversion technologies (thermochemical, biochemical, and mechanical extraction) to produce useful products (electricity, heat, and transportation fuel).

In general, the government should, first and foremost, implement its own decisions and work towards encouraging independent renewable energy producers, in general, and energy generation by WTE technologies, in particular. By doing so, the overall energy generation capacity will increase, the dependence of Algeria on imported fossil fuels will be reduced, and a significant reduction in pollution and greenhouse gas emissions will occur.

Recommendations

The recommendations of this research are the following:

Solid waste can be used as an energy source in Algeria. However, the WTE facilities must operate under strict standards, which will minimize environmental impact and adhere to the precaution principle.

Implementation of landfill disposal techniques should be encouraged for the valorization of biogas.

Waste-to-energy and valorization of Algerian solid waste is a new subject that needs to be developed.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

BTE co-supervised the work, collected the references and the informations, and drafted the manuscript. MMS co-supervised the work and corrected the draft manuscript. All authors read and approved the final manuscript.

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Received: 5 April 2012 Accepted: 25 July 2012
Published: 31 August 2012

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doi:10.1186/2251-6832-3-17
Cite this article as: Boukelia and Mecibah: **Solid waste as renewable source of energy: current and future possibility in Algeria.** *International Journal of Energy and Environmental Engineering* 2012 **3**:17.

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