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RESEARCH ARTICLE
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Electrical energy from waste and garbage: General review

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Abstract. Here we give a comprehensive overview of the current situation and trends used in the field of waste-to-energy technology (WTE) and the feasibility of the various current technologies used in the conversion process, as well as the advantages and disadvantages of each used technology in terms of benefit, cost and impact on the environment, this research also provides recent statistics on the amount of electrical energy produced from waste-to-energy conversion technology (WTE) in some leading Arab and global countries in this field. We also review the global scenario for countries producing this type of renewable energies.

Keywords: renewable energy; WTE; Gasification; incineration; pyrolysis.

Introduction:

Waste means any consumable material resulting from an activity or process, and due to the absence of its need and uselessness and intended to be disposed of, and there are many classifications of waste, including household, municipal, industrial, agricultural, nuclear, health and medical care waste.

Based on urbanization and population and industrial growth, the amount of solid waste is growing very quickly [1] [2]. Solid waste is sustainable in the environment and has an obvious effect on the economy which makes it a potential source of energy and a healthy landfill is an option for waste disposal in developing countries. Developed countries have used multiple technological possibilities to manage solid waste and convert waste into energy (WTE) and considered it a potential source of renewable energy to meet the increasing energy demand, reduce dependence on traditional energy sources and reduce the effects of gases emitted from landfills, which contribute to an increase in greenhouse gases [3], previous advantages make waste energy comes in the third place of renewable energies after solar energy and wind energy.

Integrated solid waste management requires careful selection of the appropriate technology to treat each type of solid waste, after applying a hierarchy [4] (reduce, reuse, recycle, then treat and dispose of waste properly) as explained in figure (1), in order to achieve the maximum amount of waste, benefiting the citizen and the environment, in addition to the economic impact.

Recycling waste is an economic priority. Inorganic materials such as glass and metals are collected and sold, as well as cardboard and plastic are easily sorted and recycled to produce new goods. For example, one ton of used plastic is equivalent to 220 dollars, while cardboard is sold for 65 dollars [5] and therefore the recycling process is considered important because it transforms materials from the waste stream into useful materials, in addition to that it saves the energy of waste collection and disposal [6] and among the best countries in terms of recycling are: Sweden, Austria, Germany, Taiwan, Singapore and South Korea, and are 99%, 63%, 62%, 60%, 59%, 49% successively; according to the sequence and based on what was mentioned in the global environmental protection report.

The process of converting non-recyclable waste into thermal energy, electricity, and fuel occurs through a group of processes including incineration, pyrolysis, biogas production, anaerobic digestion, thermal DE polymerization and others, often called (waste energy WTE) [4].

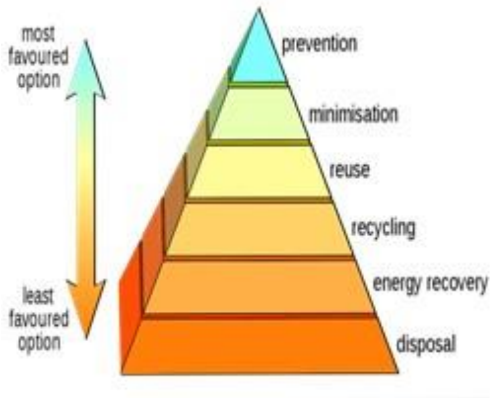

Fig (1): waste management hierarchy[4]

Many researches have been done in the field of waste-to-energy conversion technology , and some of the research teams have taken certain areas as cases for study. C.S. Psomopoulos and his research team had done a research in the benefits of converting waste to energy in the United States of America, and it was noted through their results that WTE conversion facilities have lower emissions compared to facilities producing electricity from fossil fuels, except natural gas [7], and the waste-to-energy sector has been highlighted in countries of East Asia by researchers like Maw Maw Tun and his colleagues that made a great effort in collecting research papers and found that the technologies used for WTE transformation prove that electricity production is estimated at 323-megawatt hours, and by 2030 , 17.23 TWh can be generated in six countries in Southeast Asia (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) [8]. The efforts made for waste management and energy production in the Arab Republic of Egypt were discussed, and these efforts were compared with those of leading countries in this field, such as Germany, India, China, and the United States [9]. Catherine Weber's team studied waste treatment methods in Germany and ways to convert it into energy, and it was found that the electricity production from waste is estimated at 90 terawatts, which is equivalent to 37% of energy consumption in Germany [10]. The capacity of domestic China to produce WTE equipment and the main problems and opportunities for energy access was investigated by Guangqing Huang and his team [11]. In the United Arab Emirates the status of ongoing WTE projects and WTE plants that are currently under design and construction is discussed by Zarook Sharfdeen and his colleagues. Because the UAE is one of the most important economic centers in the Middle East, It is also one of the highest waste-producing countries due to its rapid development and growth; thus, it seeks to use modern technologies to convert generated waste into energy. [12] .In Iraq Abdul-Hussein Abbas and his colleagues applied Dulong's formula [13] to evaluate the calorific value of waste incinerated in the city of Basra. It was concluded that the burning of municipal waste Solid state will produce the equivalent of 158 megawatt-hours per hour, which is equivalent to 21% of the amount of energy demand in Basra [14]. Taha Al-Tayyar and his colleague also studied the economic feasibility of waste recycling in the city of Mosul after studying the types of waste for a period of six months [5].

Technological techniques for converting waste into energy WTE:

Technological techniques are classified into the three most widely used techniques [12] and they include thermal conversion (incineration, gasification, pyrolysis, energy production from RDF), biological conversion (anaerobic digestion or biomethanol).and the third technology is landfilling with gas and overall efficiency. Figure (2) shows the techniques for treating municipal solid waste.

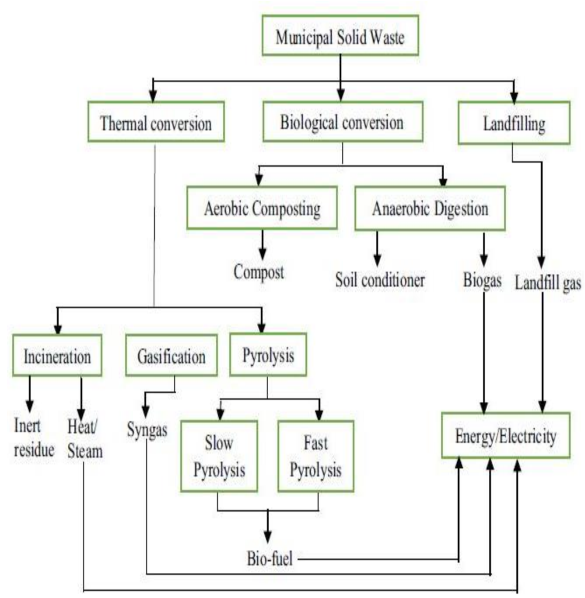

Fig (2): Municipal solid waste treatment techniques and their products[2].

1-Thermal conversion includes:

A-Incineration: This method reduces the volume of waste by 90%, but it produces a highly polluted air that needs filtering systems for the resulting air, and the remaining ash needs special landfills, then it is passed in a fast rotating kiln for fluidized materials [15, 16] ,this method costs two to three times more than recycling or burying waste and turning it into fertilizer [17]. There are 58 waste incineration facilities in the United States of America [18]. There are about 350 incinerators are operating continuously at this time in various parts of the world. In Switzerland and Japan, 8% of solid waste is treated in this way. Japan treats 40 million tons of waste annually by burning and comes in the first rank in the world in this field [18, 19]. The heat generated by burning is used for heating and electric power generation. The ash can be used in construction and building. Electricity is generated in the incinerators through a steam cycle, as the gas produced from the incinerator enters the steam boiler and produces steam, and the resulting steam moves the turbine fan and drives the generator and the last generates electricity (the electrical efficiency of the incinerators is low and forms about (14-28%)) and the rest of the energy is used as a heat [20-22]. Steam systems in waste incinerators generate 450-550 kilowatt S hours/tons and emit one ton of CO2 gas. Figure (3) illustrated a simplified diagram of the incineration process and electricity generation.

The use of incinerators in the Arab world is scarce and the only waste that's burned is hospitals waste. In the seventies of the last century, Lebanon and Morocco had incinerators that have been stopped due to the high humidity in the climate that may reach 70%, which makes the burning process very expensive, in addition to the citizens' opposition on incinerators production of toxic gases that are released into space [22].

In the eighties of the last century, incinerators' emissions were acidic and affecting the environment, as for modern incinerators, they contain primary and secondary combustion chambers and complete combustion controls with minimal emissions [16].

b- Pyrolysis: plastic materials are made from oil and the wide applications of plastic in many fields and the increased demand for plastic made an increase in the oil consumption. Plastic is converted into liquid oil through the process of pyrolysis [23], and liquid oil has calories similar to calories in the commercial fuels. The process of pyrolysis of plastic is sustainable process because the amount of plastic waste in each country reaches millions of tons, so treating the plastic waste will cause less waste burial and less environmental pollution, in addition to the economic benefit resulting from oil production [24]. The output of commercial pyrolysis systems is primarily energy or heat; Bio-oil, improved syngas, and solid waste pyrolysis coal have high calorific value [25], and if the catalysts are used in pyrolysis, they improve the productivity of the product and reduce the energy needed for the process [26-27]. One of the most active countries in pyrolysis technology is Germany, Britain, Switzerland and Italy, and this method produces less air-polluting emissions and is more efficient in producing energy than burning by 70% to pyrolysis compared to 40% to burning [2].

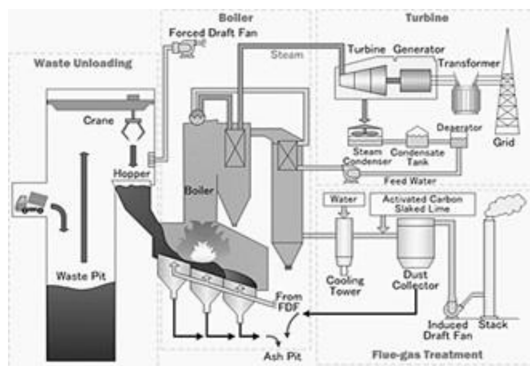

Fig (3) Scheme of the technological process of waste incineration Pollutants [14].

C-Gasification: It is a thermal conversion technique where the organic compound is converted into industrial gas (syngas) in an oxygen-controlled atmosphere and this method includes partial oxidation (air + oxygen + steam) with temperatures above 〖550〗 ^° resulting in gases (CO,H,CO_2) and waste. Petroleum and industrial gas are used in generating electrical power and produce heat. Industrial gas can be converted into methanol, ammonia and industrial gasoline. It can be used as an alternative to natural gas or mixed with natural gas [28].]. The gasification costs range from (40_100) $ per ton, and these costs include operation and maintenance. This method produces less quantities of toxic waste and air emissions compared to incinerators [29][30]. Gas turbines generate between 900-1200 kilowatt-hours of electricity, twice what is achieved by the steam cycle used in burning. The cost of establishing a waste gasification plant with a capacity of 680 tons per day is estimated at 150 million dollar. Municipal solid waste gasification technology is widely used in Japan and 85 factories operate since 2007[31]. Asia witnessed a huge leap in gasification technology in the past few years and it can be considered as one of the most suitable countries for gasification technology followed by Europe, Africa and. USA [32].

There is a method of gasification called plasma gasification. Plasma is the fourth state of matter after solids, liquid and gas. Plasma is a very hot, electronically charged gas naturally generated by stars in the universe. Plasma can be artificially generated on Earth through the use of electrical energy. Organic and inorganic waste can be treated through a reactor that uses a plasma burner to increase the temperatures to thousands of degrees [33][34][35].

D-Energy output from (RDF):The (RDF) is a solid fuel made after basic treatment techniques that increase the calorific value of municipal solid waste, where the waste is cut then heated then cut and formed to produce (RDF) and the (RDF) can be gasified or treated by pyrolysis method at a temperature of 750 Celsius degrees . A synthesis gas yields 0.43 m3/kg of (RDF) [36].In Iraq there is a factory for waste treatment and the production of (RDF) located particularly in the city of sulaymaniyah, this factory treats about 1,100 tons of waste per day and uses (RDF) as fuel for cementing plants instead of black oil.

2-Anaerobic digestion:: This method is used to produce biomethanol with wet organic waste. Anaerobic digestion is a biological process in which organic waste is broken down by bacteria into simple molecules, and biogas is produced, divided 60% methane and 40% carbon dioxide [37]. For every ton of waste the treated anaerobic digestion produces in 3 weeks methane gas equivalent to (2-4) times more than what is produced in landfills for 6-7 years, and methane is used to generate renewable energy in the form of electricity and heat, and a cubic meter of methane generates 2.04- kilowatt-hours, the cost of anaerobic digestion is $12 per ton and the anaerobic digestion process reduces the percentage of waste up to 85% [38][39].

3-Landfill with gas recovery: It means the disposal of waste in a controlled manner to reduce the negative impact on the environment through the recovery of biogas and the control of the leachate from the waste [40]. Burying of municipal solid waste is often more economical than burning waste in incinerators [41-43], and developing countries dispose of the increasing amount of waste through unsanitary landfills, which poses a serious threat to the environment [44].Landfilling is the worst option when the environmental and health impact and groundwater pollution are taken into consideration, and according to experts, only (10-15%) of the total waste should go to the landfills [45].The prevailing technology in North America for waste disposal in sanitary landfills with gas recovery [40] and recovered methane gas is used to generate electricity and heat [46]. Sanitary landfills are required to reduce odors and reduce emissions of thermal combustion gases by burning them and eliminating any leakage of leaching [47] and landfills use linings to prevent the leakage of liquids into the groundwater. Figure (4) shows a sanitary landfill.

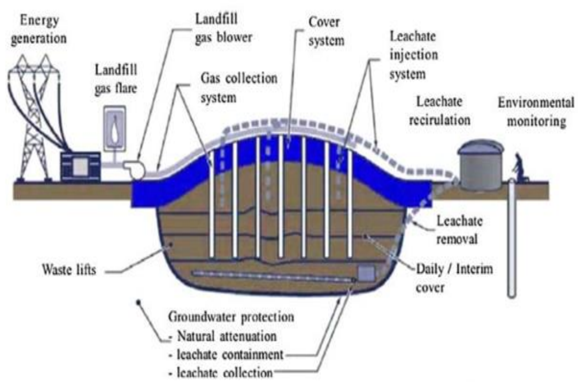

Fig (4) A typical engineered landfill with biogas recovery system [48].

The current scenario for the production of electrical energy from waste at the global and Arab levels:

The increase in the population, the rapid urban development, the improvement of the standard of living for many citizens, and the change in lifestyle and consumption, all helped to increase the amount of municipal waste (organic, solid). Waste treatment methods differ from one country to another. The website of the international Renewable Energy Agency (IRENA) provides information about the amount of electrical energy produced from waste and all waste-to-energy technologies worldwide for several years. Electricity is generated after waste treatment in some of the world's leading countries, in this field China leads the world in the production of electrical energy from biomass with 82,250 MWh in 2019, according to a report from (IRENA), followed by the United States of America with 63,194 Gigawatt-hours, then Brazil, Germany, the United Kingdom, Thailand, Japan, India, Italy and Finland [49][50]. The chart in Figure (5) shows the top 10 countries in the production of electrical power from the treatment of municipal solid waste.

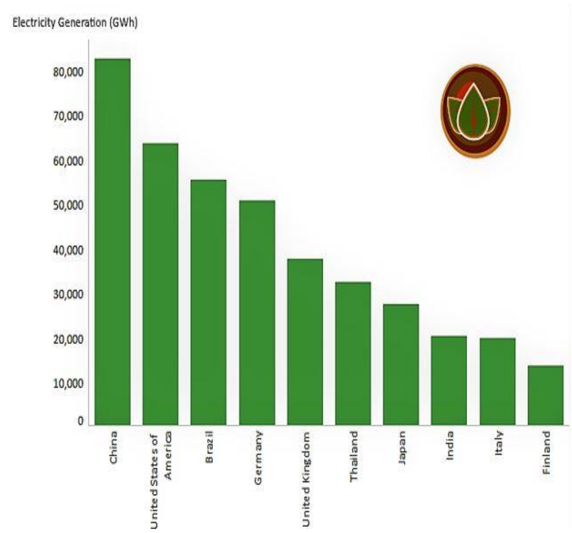

Fig (5) the top 10 countries in the production of electrical power from MSW [50].

In Sweden, the recycling system is the prevailing system and treats 99% of waste and only 1% in landfills. Sweden surpassed all countries in the world and has turned garbage into gold since the seventies of the last century, every 4 tons of waste equals a ton of oil, and all garbage trucks are working on gas derived from garbage, and 20% of heating from garbage energy, incinerators get $43 for every ton of garbage, Sweden produces 14 kilowatt-hours of electrical energy [50], and citizens are encouraged to sort garbage and deliver it for recycling, A system of active fines and advertising helped in training Swedes to separate waste. Recycling is taught as a methodological subject in kindergartens, as is physical education and music, and they produce everything from recycling such as sportswear, carpets, and others. Figure (6) shows the increase in the production of electricity from garbage between 2010 and 2019, it also shows the top five European countries that are superior in this field.

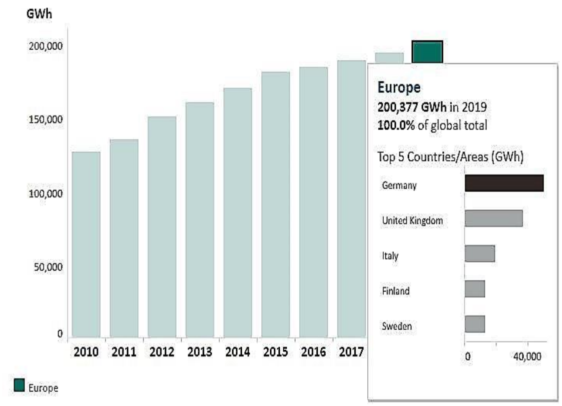

Fig (6) The top five European countries in the production of electricity from the garbage in 2019[50].

Waste in Japan is divided into 4 categories (combustible, non-combustible, recyclable and large) and the waste is placed in special bags with special sizes and colors. Each category has a special color, for large wastes they must be disposed of separately. To get rid of the refrigerator, for example, you have to pay an amount and they give you a sticker that you put on the refrigerator to distinguish it and transfer it to the trash. This method led to save 20 million tons of iron and 50 thousand tons of minerals other than iron, and Japan launched the term zero waste where garbage is incinerated by plasma gasification at a temperature of 1200 degrees Celsius and in this way no tar is formed, leaving 30 tons of garbage 6 tons of ash that is cleaned and used in construction, such as Odaiba Island in Tokyo Bay, where the bay was filled with rocks and coarse powder resulting from burning waste was added. It has a light layer of soil and these materials became the basis for the island on which a luxury residential complex, restaurants, metal factories, and Tipo International Airport were built, in addition to green gardens. 20 tons of waste produces a ton of new land. Japan increased the size of the country from garbage.

In New York, 120 thousand tons of garbage is burned per hour after the garbage is dried for 7 days and the metals are removed by the force of the magnet, and the temperature of the incinerator reaches 2,200 degrees and the blazing fires feed high-rise boilers 165 feet high, and the resulting steam is used to move electrical power turbines [51].

One of the leading Arab countries in converting waste to energy is the Kingdom of Morocco, Egypt, Qatar, Emirates, Jordan, and Syria [50].figure (7) shows electrical power production from MSW in eight Arabic countries.

Since 2016, sorting from the source has started in Qatar and awareness has begun in schools. The Mesaieed Waste Treatment Factory produces (75-80) tons of fertilizer, in addition to 4000 tons of new paper per month. The Doha Plastic Factory also produces 700-1000 tons per month of farm pipes, where bottles are collected. The water is washed and milled to obtain raw granules and rotated to make tubes, and tires are recycled where they are cut and materials such as flax, flax granules, and steel are extracted. Turkey produces 3505.67 Gwh of electrical energy from waste annually using various technologies.

UAE: The large accumulation of waste at a time when oil and gas reserves are decreasing greatly encourages the use of (WTE) technology in the United Arab Emirates and the leading company in this field in the UAE is (Masdar) company, which adopts the method of incineration, while (Bee'ah) company adopts the Gasification method and Pyrolysis , Bee'ah plans to build a plant that uses gasification and pyrolysis and will treat 400,000 tons annually of waste, with a production capacity of 85 megawatts, which will provide energy to 50,000 homes [53] , that biogas produced from waste in the UAE generates 229.8 Gwh. According to the report of the World Renewable Energy Organization in 2019 that biogas produced from waste can generate 18 MW for Abu Dhabi, which is equivalent to 7% of its energy from renewable sources [54] and Abu Dhabi's gains from generating electricity from biogas and fertilizer is estimated 30 million dollars.

Iraq: There are a few facilities in Iraq dedicated to waste treatment, and this facility belongs to Kurdistan region, where there is one in Sulaymaniyah, another in Duhok for waste separation, and another one in Erbil for recycling cartons, but there is no governmental or private sector facility in all cities of Iraq until now.

Now environmental and economic specialists are working hard to include this issue within the state's plans to address the increase in waste and turn it into renewable energy sources. The population is increasing, and with this increase, waste increases according to the individual's productivity of waste, and all of it has been thrown into uncontrolled environmental and health dumps.

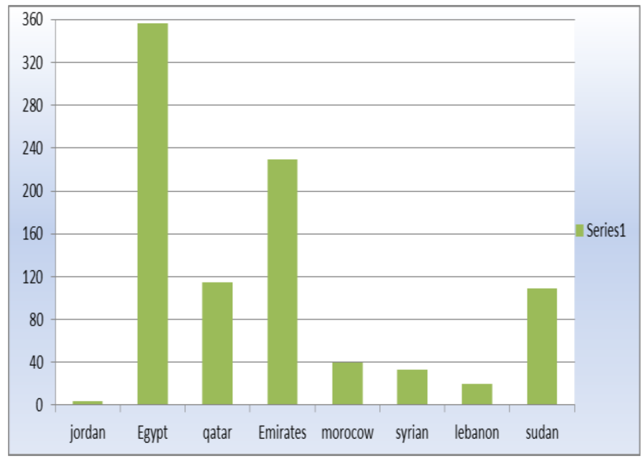

Fig (7) production of electric power from MSW in eight Arabic countries [50].

Conclusions:

1-The most abundant source of renewable energy on earth is the mixed municipal waste and waste from farms and food industries, and after reviewing all available technologies in (WTE), it can be concluded that the most possible solution in developing countries is the technique of anaerobic digestion of organic waste due to the dominance of food and organic materials on waste components.

2-The efficiency of converting waste into electrical energy is equivalent to 45.3% of the efficiency of converting fuel to electrical energy, meaning that each metric ton of incinerated waste generates (507 kwh).

3-The higher the moisture in the organic waste, the lower the burning efficiency,therefore, organic waste must be separated from the waste that can be recycled.

4- Waste recycling has many important benefits, in addition to providing the energy needed to treat waste, it stimulates the development of environmentally friendly technology, reduces emissions of polluting toxic gases, provides industries with raw materials, creates job opportunities, reduces the need to establish new landfills and maintains natural resources.

5- All emissions resulting from alternative energy sources (furans, dioxons, mercury, lead, cadmium, hydrolic acid, sulfur dioxide, and particulates) resulting from converting solid waste into energy, are less compared to the emissions resulting from burning fossil fuels.

6- To encourage the production of energy from waste, it must be promoted in the form of tax exemptions and subsidies provided by governments to investors to contribute in increasing professionalism and developing resource management.

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