

A feasibility study of electrical energy generation from municipal solid waste in Iraq: Najaf case study

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ABSTRACT

In several developing countries, the electricity crisis obstructs both socio-economic and technological sustainable evolution. Also, it leads to reducing job availability due to shut down several industries or relocate to neighbouring countries to such an issue. A Najaf City is an important holy and tourist city in the middle of Iraq country. Indeed, waste management in An Najaf City needs to be reconsidered to be used as an energy source. In this article, we investigated and listed the waste quantity which produced recently (one year) respect to waste types and types of content. Data collected from the waste products for one year and are used as a key factor to study the feasibility of generating electrical energy from collected MSWs. The proposed model was simulated and tested respect to cost analysis factor of the suggested power plant by Homer pro simulation software. Results were very encouraging and competitive to the current energy production cost based on the production cost of the Kwh prospective among the conventional methods in Iraq. The proposed scenario provide proper and secure waste proposal technique with low-cost.

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1. INTRODUCTION

In the current era, shortages of the energy sources, changing the global climate, and world energy conflicts lead to negative effects to all levels of the society and threatened world stability was increasing. These challenges can be decreasing the fossil fuel reserves to the growth of the world population, Global climate change, and Increased in wastes levels (solid/liquid) and can be resulted to electricity crisis. Diverse strategies have been investigated and studied to generate alternative energy [1, 2]. These strategies are considered significant, especially for future world stability [3, 4]. Hence, renewable energy sources in particular organic waste materials to energy is becoming an important attractive substitute in the near future [5, 6]. Several Renewable waste materials sources are used to generate alternative energy like from agriculture [7-11], industries [12-18] and domestic [19-23]. These sources are adjustable to beneficial energy forms such as biohydrogen, biogas, bioalcohols, etc., through waste-to-energy routes (WTERS) for prospective growth of the world.

Municipal solid waste (MSW) is one of the renewable sources of energy in the traditional way. MSW points to materials discarded in urban areas which are collected and disposed of by the municipalities and it is counted a source of biomass due to it is a significant fraction of waste materials like leather, food waste, wood, and yard trimmings, and paper [24, 25]. Biogas is one of the efficient energy sources due to

a small scale cost-effective and can be produced by using organic materials like several wastes [26]. In Iraq, although significant additions to the generation energy have been made recently and with available capacity expanding by 8 gigawatts (GW) (or 90%) between 2012 and 2018). However, this has not been matched by improvements in the condition of the power grid or reductions of losses (technical and non-technical). Several challenges such as Iraq damage wrought by ISIS war against and constrained budgets that lead to not producing enough electricity to satisfy demand. Besides, Iraq's population is growing at a rate of over 1 million per year. Hence, electricity demand is set to double, reaching about 150 terawatt hours (TWh) (17.5 gigawatts [GW] average throughout the year). Thus, Iraq faces a profound need to develop its domestic energy infrastructure, in particular in the electricity sector to avoid these issues.

Several studies have been attempt in previous five years to study and analysis the possibilities for electrical energy production by using municipal solid waste via diverse aspects. In [27], presents the potential of electrical energy production by using municipal solid waste disposed in biggest Brazil cities such as São Paulo from landfill gas. The study includes two scenarios could replace 27% and 13.5% of the residential electrical energy consumption in the city. Another study in Brazilian municipalities is presented in [28], the study aims to analyse the techno-economic feasibility of municipal solid waste gasification to generate the electricity possibilities. The results of the proposed scenarios several pros such as increase the economic feasibility, providing a positive scale up gains that leads to lower installation and high benefits and lower costs as well. On another side, different researchers via several developing nations tried to study and analyse the potential of electrical power generation from MSW.

In [29], proposed an assessment study to generate electrical power from MSW in Rajshahi City Corporation Bangladesh. The study had the ability to generate electrical energy from MSW in RCC city is 5.336 MW and 10.568 MW during the years 2012 and 2025 respectively. In [30], two phases are aimed to examine waste-to-energy development and evaluate its success factors respect to modified Sweden's waste-to-energy model in Nigeria for WTE capacity enhancement purpose. The study results were the proposed model able to generate around 2.0 TWh of electricity from about 5.7 million tonnes of waste in its WTE plants in 2014. In Iraq, the study in [31] was conducted to product electrical power from MSW in Basrah Governorate which positon in in the south of Iraq. The study was able to generation electricity which will translate into approximately US\$ 69 million in revenues per year from the WTE plant. As well, it provide the maximum capacity for power generation is projected to be around 270 MW in 2036 with discount rate of 12% of the WTE.

The key aim of this article is to examine, investigate and appraise the possibility of generating the electrical power from municipal solid waste in An Najaf City in the middle of Iraq. The waste is classified into population subgroups that used as a key factor to study the feasibility of generating electrical energy from collected MSWs. Homer pro simulation software is used to simulate and testing respect to cost analysis factor of the suggested power plant.

2. METHODOLOGY

2.1. Waste in Al Najaf City

Waste accumulation, collection and liquidation, and burning waste in the environment resulted in several diseases like serious skin infections or exposure to tetanus and other health risks in addition to it caused environmental risks such as Foul odours emitted from waste and distortion of the landscape of the city [32]. Waste management and treating in different countries done by classifying waste subgroups according to their type as a beginning (paper, cardboard, materials glass, such as glass flasks, metal materials, plastic materials, etc.). Thus, it requires a manpower effort for initial screening by workers and the second stage is to sort and classifying MSW to subgroups [33].

Al Najaf City is one of the Iraqi central provinces and is divided into multi-sections and each department concerned with the collection and transportation of waste in its area. Najaf Municipality Department is responsible for the collection and transportation of waste as well as the municipality of Kufa, Al Hayderiah, etc. Data listed below are specific to the Municipality of Najaf department. Where the city divides into six sections as shown in Figure 1. Waste in the aforementioned areas are collected and transported by Iraqi machines and workers in two kinds depends on the investment:

2.1.1. Najaf Municipality Department workers and machines

The total of 466 regular workers and 218 machines that include tractor and garbage trucks, in addition to 158 drivers were deployed. Table 1 lists the number of workers and machines of the Najaf Municipality.

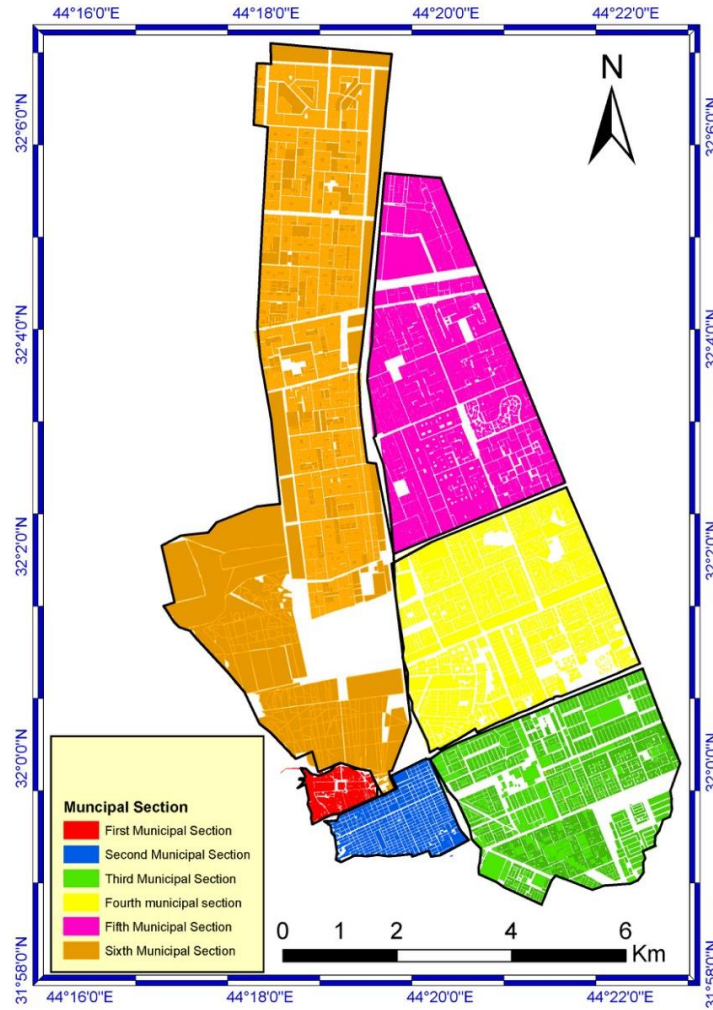


Figure 1. Six sections represent Najaf City sections

Table 1. Workers and machines in the Al Najaf Municipality Department

Area section	Number of worker	Garbage truck	Truck
First municipal section (Q1)	4	13	7
Second municipal section (Q2)	14	19	10
Third municipal section (Q3)	24	15	10
Fourth municipal section (Q4)	16	19	10
Fifth municipal section (Q5)	28	27	11
Sixth municipal section (Q6)	14	15	11
General Parks	228	0	18
Direct implementation	0	0	4
Landfill & terminals	0	0	3
Mechanics & workshops	6	7	7
Raising dust	64	0	12
Traffic engineering	10		

2.1.2. Najaf Governorate Council workers and machines

The total of 620 workers and 49 garbage trucks are deployed to collect MSW as shown in Table 2. The cost which paid from Najaf governorate council to the workers and machines per month will be around 355,000,000 three hundred fifty-five million Iraqi dinars (IQD). Based on results in Tables 1 and 2, the total workers and machines in these areas will be: 620 Najaf governorate council workers, 408 Najaf Municipality Department workers, 114 Garbage truck, 152 truck, 45 observers, and 238 divers respectively. The residential and commercial waste amount for each section (Q1 to Q6) per day and year is shown in Table 3, in addition to the 2016 population.

Table 2 Workers and machined numbers in the Al Najaf Governorate

Area	No. of workers	Number of observers	Number of tractors
Q1	130	4	
Q2	90	4	2
Q3	94	4	13
Q4	90	6	10
Q5	134	10	14
Q6	72	4	10
Additional observer			7
Station workers			5
Agricultural engineer			1
maintenance observer			5
control observer			1
Drivers			80

Table 3. The residential and commercial waste amount and 2016 population

Area	No. of Housing units	Population 2016	Residential units waste	Commercial units waste	Waste (ton/day)	Waste (ton/year)
Q1	3058	21406	21	150	171	62415
Q2	20850	145950	146	30	176	64240
Q3	16793	117551	118	24	142	51830
Q4	21912	153384	154	30	184	67160
Q5	30303	212121	212	43	255	93075
Q6	28410	198870	199	0	199	72635
Total	121326	849282	850	277	1127	411355

A total number of inhabitants in these districts in 2016 is around 880 K (eight hundred eighty thousand people) and the total waste per day for these areas is 1127 tons (one thousand and one hundred twenty-seven tons). By dividing these amount of waste among the number of people to get the percentage of waste per each one, 1.28 kg per person. Directorate collects and transport wastes from the sections above to central areas in the neighbourhoods of Abu Talib and Alquds and then to the landfill area behind the Al-Nida neighbourhood.

Quantity of the waste for one year will be more than 400 k (four hundred thousand) tons annually. This process is not beneficial to municipal departments and is consumable for them. These wastes continue to exist because there is no fixed time for waste disposal by citizens, as lifting process takes place normally in morning and evening. Waste in the city is almost consisting of paper and cardboard, glass, such as glass flasks, metal materials, plastic materials, etc. [34]. Table 4 lists the ratio of waste management regarding several materials and components.

Table 4. Waste components

Components	Percentage %	Components	Percentage %
Food waste	68.17 %	Textiles	5.09 %
Paper and cardboard	9.6 %	Baby diapers	1.9 %
Glass	2.3 %	Residues of gardens	0.93 %
Plastic and nylon	5.29 %	Wood	0.85 %
Food packaging	1.42 %	Rubber	1.0 %
Aluminum cans	1.4 %	Leather materials	0.48 %
Metals	0.98 %	Another	0.59 %

Quick steps to solve the waste problem in a timely manner are possible by providing certain types of equipment and some requirements such as:

- Select a specific area for the collection of waste in special containers.
- Distribution of waste collection bags.
- Agreement to lift containers or empty them with the contractor or by the municipality.

Above steps are mostly the choices of municipal departments in the province for waste management and it's clear that they are insufficient.

2.2. Waste management

There is requiring to increase the citizen's awareness to reduce, isolate, and classify waste to several types (paper, glass, plastic, etc.) to reuse it again and be more helpful for recycling [33]. Recycling refers to the process of compiling materials and sorted them by its types to be more suitable for manufacturing and reusable materials [35]. This process has many significant such as reduce pollution of the environment,

create new job opportunities, preserving the sources of natural materials, and reduce reliance on raw materials. Thus, increased the environmental awareness of the citizen will lead to making people follow rules to avoid waste issues and benefit from their waste. Also, the distribution of different bags colours can be a classified type of waste contained (blue colour of waste plastic and green for waste food, etc.) or can divide it into simple sections by citizen (such as paper waste, plastic waste, glass waste, etc.). Based on the distribution result strategy, waste can be utilized by selling it to collection centres in the neighbourhoods (selecting a specific area for collection of waste in private containers for each neighbourhood) and waste assessed by its type and placing these amounts in the waste owner's account using prepaid card systems. Hence, this mechanism will motivate to make people high benefit from their waste disposal.

2.2. Waste to energy (WTE)

Several technologies have been used to disposal waste to reuse and convert waste to electricity power such [31]. These technologies such as incineration, gasification, pyrolysis, combined pyrolysis, gasification, combined gasification-combustion, and plasma gasification/verification [36]. Gasification method is selected in this study due to low capital investment, simple, and available waste disposal techniques in An Najaf City and can be a suitable technique to be deployed.

2.4. Gasification

Gasification is one of the methods used to treat, reuse, and convert waste via digging a hole in the ground and put the waste inside and cover it with soil afterward [37-39]. Then, the soil will absorb large amounts of waste without the need for advanced technology in addition to low cost. However, decomposition of waste leads to leakage of toxins to groundwater or surface water sources with soil pollution, which affects the agriculture and food cycle in addition to pollution of drinking water and thus increasing the dangers to the lives of citizens. In addition, it also transmitting air-polluting gases, leading to many risks to all living creatures, as it affects breathing air as well as the emission of unpleasant odours, but all disadvantages can be solved by selecting the suitable place to minimize any undesirable effects. Thus, waste should be covered with a layer of soil for maximum benefits from these gases by using biogas technology.

3. RESULTS AND ANALYSIS

3.1. Case study and simulation scenario and evaluation metrics

In this study, the collected wastes in An Najaf City for one year are used to generate electrical power and study the feasibility by simulating the case study with Homer Pro software [40, 41]. A scenario which is assumed with biogas gasifier (generator) is simulated with Homer Pro and fed with the available data of the collected waste from the six sectors of the city and with the parameters shown in the Figure 2 for one year as a timeline. Information from Table 3 is fed to the biomass source of the generator as shown in Figure 3. Information from Table 4 is used to model the biogas fuel parameters as shown in Figures 4 and 5. Average monthly temperature effect also was included in the simulation. As shown in Figure 6. The temperature data is taken from climate and weather averages in Baghdad, Iraq.

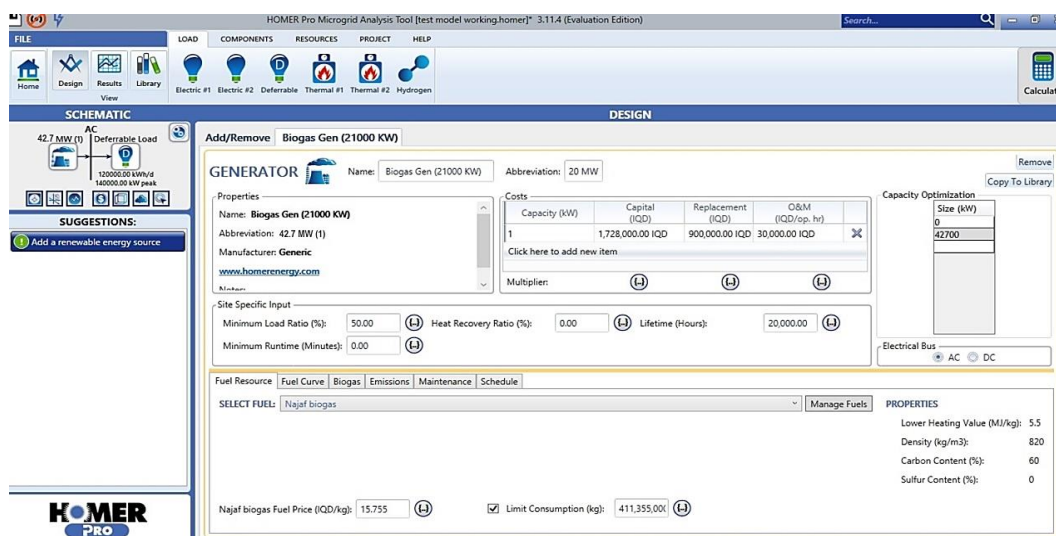


Figure 2. Homer pro micro grid analysis tool

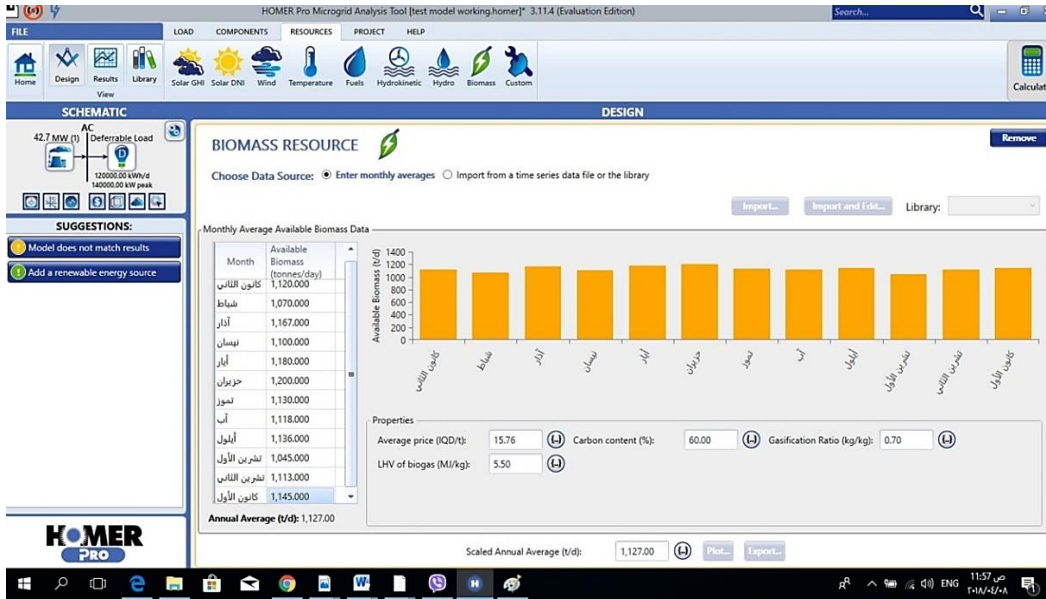


Figure 3. Biomass resource

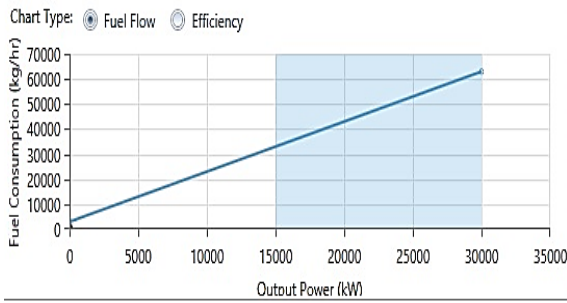


Figure 4. Fuel flow diagram (using data given in Table 3)

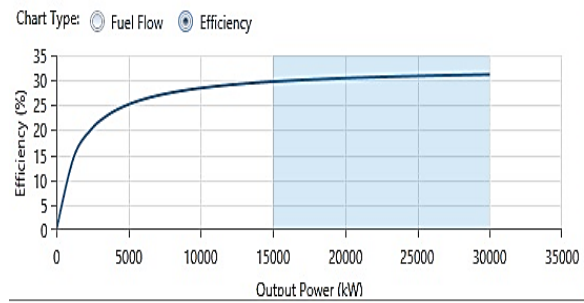


Figure 5. Fuel efficiency diagram (using data given in Table 4)

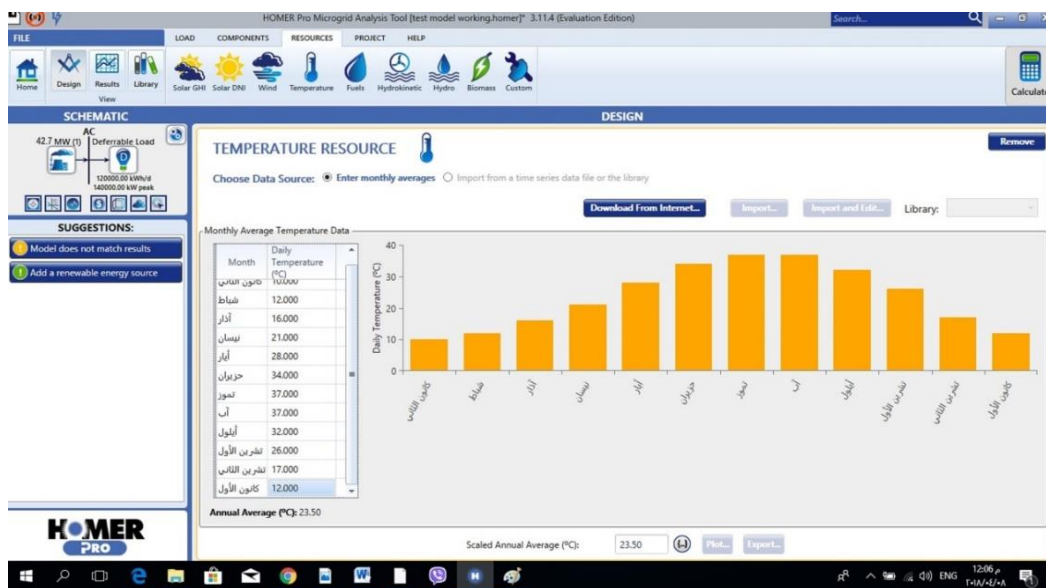


Figure 6. Temperature data average in Baghdad, Iraq

3.2. Simulation results

In the feasibility study which introduced in this work (Section 3.1), the start parameter was the total amount of the collected waste per year, in Najaf City which was costed 411355 ton/year. This amount of waste costs a lot of money and efforts to properly landfill, so this amount was assumed as a fuel input for a gasification power plant simulated with Homer pro evaluation copy software. The simulation results shown in Figure 7 shows that a power plant with the given amount of waste as an input can produce around 42.7 Mega Watt and about 187 million KWh/year. The cost analysis results shown in Table 5 are very encouraging to adapt to this scenario in real settings.

The total operating cost is around 11240 Billion IQD per year which includes besides the plant's operation and maintenance cost the waste collecting cost (labors and machinery costs). Currently, the Kwh average cost produced from the conventional power plants in Iraq according to the ministry of electricity report [42] is 106 IQD. A rapid calculation can show that the average cost of kWh produced from the assumed plant is 60.1 IQD, and the cost difference is very noticeable. The capital cost for such a plant is around 500 USD (US Dollar) = 600000 IQD for Kw [43], so the total initial capital cost for the assumed plant is around 25.62 Billion IQD. From the difference in the average cost of the kWh, it's clear that the refund of the capital cost will be done in three years only.

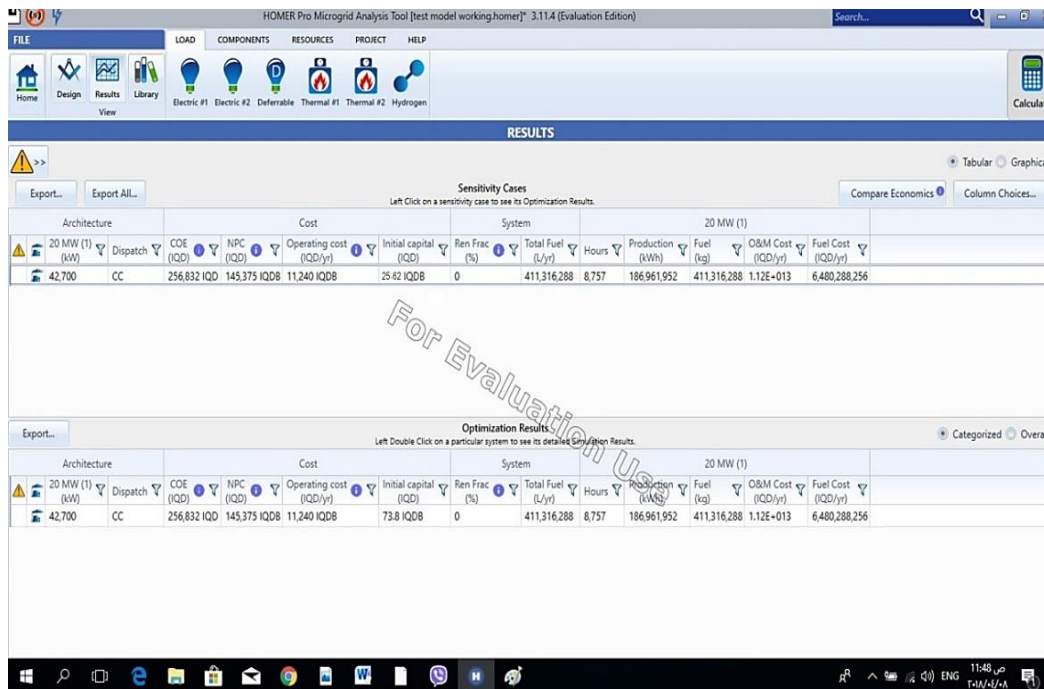


Figure 7. Homer pro simulation results

Table 5. Homer pro case study simulation results

Cost of Energy IQD	256.832 IQD	Net Present Cost IQD	145.375 IQDB
Operating Cost (IQD/Yr)	11.240 IQDB	Initial Capital IQD	25.62 IQDB
Total Fuel (L/Yr)	411.316.288	Hours	8757
Production (kWh)	186.961.952	Operation & Maintenance Cost (IQD/Yr)	1.12E.+013
Fuel Cost (IQD/Yr)	6.480.288.256		

4. CONCLUSION

In this study, the produced waste from An Najaf City is discussed and a few remarks to manage the collection process of the waste is suggested. Currently, the waste disposal method in the city is random and cause a lot of health risks, so a feasibility study is made to find out the financial feasibility for using the waste to generate electric energy by gasification method. The total waste produced in one year is fed to a simulated gasifier with Homer pro software to calculate the produced power and the cost breakdown of it. The results have shown that the produced energy costs less than the average cost of the Kwh produced by Ministry of Electricity (MOE) Iraq with the conventional method by (42.5 %). The produced waste from

An Najaf City can generate around 187000 Mwh/year with a 42.7 Mw plant. The initial capital cost can be refunded within three years which make the project feasible from the environmental, financial, and health point of views. The study if applied also will solve the problem of the budget of the current waste collection procedure in the city since this budget is included in the production cost of the kWh in the feasibility study.

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