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Study the Investment Opportunity of Hybrid Energy Resources (Biomass and Solar) System; Iraq as a Case Study

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ABSTRACT

The increasing world population and demand for fossil fuels for energy generation have defect the environment due to pollution and global warming. Therefore, it provoked the world to focus on renewable energy resources. Solar power and Biomass are among the good available renewable energy sources in most parts of the world. Combining both sources is a promising way to reduce greenhouse gas emissions and a reliable investment in energy. However, this type of energy has yet to be considered seriously in Iraq. This research uses theoretical and experimental studies to evaluate the energy production from hybrid energy sources (Biomass and solar) in Diyala province, Iraq. The practical part focused on creating a small-scale prototype to verify the success of Biomass in Iraq and then expand on a large scale. Moreover, the gas generated has a more economically viable and helpful heat source for cogeneration power plants. The expected electricity production from wasted food in Iraq is about 38.5 MWh. Finally, this study can be a good advantage in investigating the feasibility of operating a hybrid solar-biomass power plant in Iraq.

1. Introduction

The sun is one of the essential energy sources, and the energy flux density is 63 MW/m^2 in all directions. According to Evans *et al.,* [1], the Earth receives solar energy 1.7×1014 kW, and the energy flux density on the Earth's surface is about 1 kW/m^2. Furthermore, the point that reaches the Earth's surface is estimated to be about 10,000 times. However, the challenges of finding independent renewable energy resources were enormous because of the high initial cost and non-continuous and renewable energy resources such as solar, wind, and biogas [2].

Establishing a hybrid power plant idea was very interesting in several ways and promising as an alternative electric power resource [3]. On the other hand, stated that the solar activities available for investment in Iraq depend on sufficient factors such as the intensity of solar radiation [4]. Also, Iraq is at the second level of solar radiation exposure because it has the sun's energy per day ranges between (4.5 - 5.4 kW/m^2) and it always exposure to solar energy for over 3000 hours per year [3].

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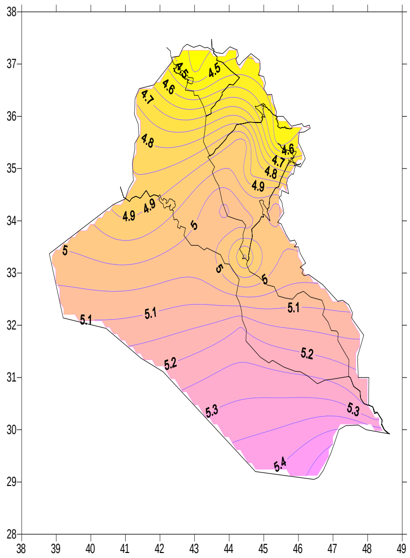
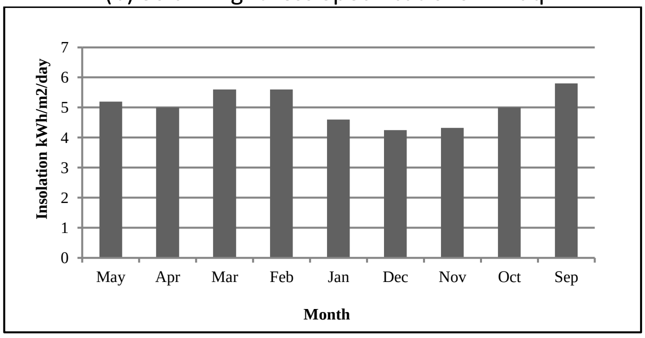
Figure 1 shows that Iraq is one of the good countries for implementing solar collector projects. Because it owns a maximum solar intensity of about 630 W/m^2 [5,6].



Range of Sun brightness between (2800 to 3300) hours/year
The highest actual brightness of the sun is in June at 11.4 hours/day and the lowest in January by 6.3 hours/day
The maximum temperatures range from 16°C in January to 44.4°C in July
The minimum temperatures range from 4.4°C in January to 25.4°C in July

(b) Solar Brightness Specifications in Iraq



(a) (c)

Fig. 1. (a, b) represents the solar shining and specifications for different locations in Iraq, and (c) covers the daily average of the horizontal solar radiation in Baghdad [3]

Ferguson *et al.,* [7] mentioned that recent research suggested that building new renewable energy devices will be cheaper than running fossil fuels in Europe alone by 2024 and 2027. Human waste food represents a huge part of daily disposal things. This waste could be used effectively to generate electricity, since this food can generate gases during decomposition [8]. The waste food in Iraq represents free things, as most other countries do, but some people will be happy to pay to collect their waste. Therefore, in this study, a field survey to benefit from this research to locate the number of landfill sites and waste scattered in all Iraqi cities (legally and randomly). The waste collected daily is about 29023.5 Tone/day, and Figure 2 shows this distribution.

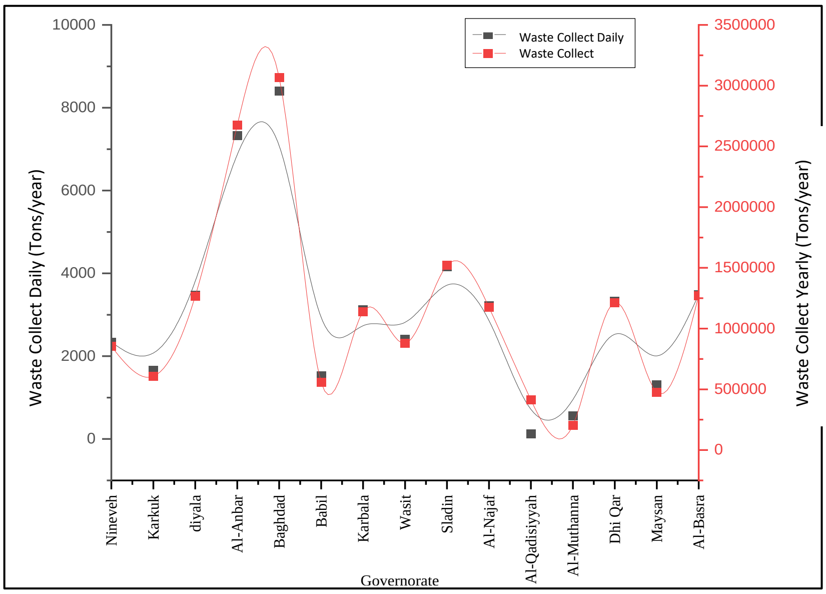


Fig. 2. Amount of waste collected according to the Iraqi governorates

There are a variety of materials and methods for generating methane, including agro-zootechnical waste, sewage sludge, anaerobic digestion, and human waste by using different biomass processes like combustion, gasification, and anaerobic digestion [9]. Table 1 explains how much the world uses methane gas to produce electricity by running the power plant, vehicle fuel, and raw materials. Concentrating on an auxiliary source of steam generation is enhanced in weather with low solar radiation.

Table 1
Global energy production of methane gas

Country	Product Type Electric power MWh	Reference
Turkey	53	Ozer *et al.,* [10]
Russia	6,3	Ialongo *et al.,* [11]
Ireland	3.6	Raboni and Urbini [12]
Netherlands	4	Raboni and Urbini [12]
Denmark	3	Raboni and Urbini [12]
Japan	3.5	Oyama and Masutani [13]
Qatar	34.4	Abiad and Meho [3]
Bahrain	25	Abiad and Meho [3]
UAE	100	Abiad and Meho [3]
China	60	Martinez *et al.,* [14]

Country	Reference	Another Product Type
Jordan	Alkhalidi *et al.,* [5]	Using methane gas production plant with a capacity of 60 tons per day (420 m^3/h) and used as fuel for vehicles.
Austria	Nowak *et al.,* [15]	The "Sabatilo" gas power plant burns 250,000 tonnes of waste every year, which it generates: • 500,000 MWh in the form of central heating. • 6000 tonnes of iron.

The exploitation of this waste may benefit humans and the environment by turning it into a good opportunity for sustainable development in Iraq to promote health reality and create new sources of electricity. Conversely, the Iraqi government has yet to act firmly on using this dual-benefit technology. The world has a good attempt represented in biogas production by projects that have strengthened the work of electric power plants. This study attempts to take advantage of the intensity of solar thermal radiation. Concentrated solar power uses solar thermal energy with a storage system and heating fluid effectively in suitable solar energy applications for hybrid systems [16,17].

Iraq is one country that needs to use renewable energy to reduce greenhouse gas emissions to provide good sources of energy, especially for remote areas, villages, and rural areas.

2. Novelty of the Proposed Work

The novelty of the proposed work lies in using biomass and solar as the function of power generation in Iraq. Diyala province is located in the middle east of Iraq and it relies on gas and diesel power plants. Despite the various climatic and political reasons, over 60% of the governorate’s residents live in city centres and generate vast amounts of solid and liquid waste, which means promising opportunities for investment and energy production along with biomass. It represents the latest study to determine the amount of daily and annual waste in Iraqi cities.

In the future, the design of this system will use a non-condensing steam turbine (back-pressure steam turbine) that uses high-pressure steam for the rotation of blades (TBU 200). Hence, the proposed method provides a practical to produce electricity from conventional concentrating solar power (CSP) and biomass. The contribution of the biomass in the thermal boiler was estimated, considering the radiation throughout the year [18].

3. Methodology

The model aims to investigate the extent of the economic and practical benefits of using biogas in Iraq. This model designed a hybrid-powered system by connecting parabolic solar collectors (TPC) solar collectors with a hybrid thermal boiler (biomass and solar) for heating the water or generating the steam and it used local materials (cheap) to build this proposed system. It investigates the performance of the proposed method and the terms of the thermal performance that are applied. The proposed model is divided into three circuits in Table 2 and shown in Figure 3.

Table 2
Specifications and components of the proposed model

Parameter	No. of parts	Specifications	Diminution
(TPC) [5]	1	• The generator temperature is about 140°C with a system efficiency of 18 %. • The average efficiency at optimum design could reach 67.5 %. • Collector's area AC= 2.5 m^2 • It is using (oil) as energy transferring medium in the absorbing tube.	• Heat flux rate absorbent from solar energy ≈ 300 W • Tabsorbing tube ≈105°C • Tgenerator tube ≈ 80°C
Steam Drum	1	• Horizontal drum • Basic Homogeneous Mixture Mode • Storage capacity (500-800) L • Mass flow rate≈2.5 kg/min.	• The ratio between the high to a diameter about (2.5:1)
Hybrid Thermal boiler (Biomass and Solar)	1	• Thigh ≈ 300°C • Working on gas (biogas) • The heating flame radiation (directly without any intermediary) • If the boiler reaches the required temperature, the gas flow stopped. • The efficiency ≈ 80 %	• Heat capacity output ≈ 1150 kw • FLOW @ Δt=40˚C between (50-60) m^3/h • Heat exchange area ≈ 56 m^2 • Pressure (2.37 bar) @ Toperating 260°C
Biogas System	1	• Performance:80 % • The feedstock used is waste with an average of 2 metric tons per day. • The system consists of a 0.6 kW biogas generator.	• Variable as needed

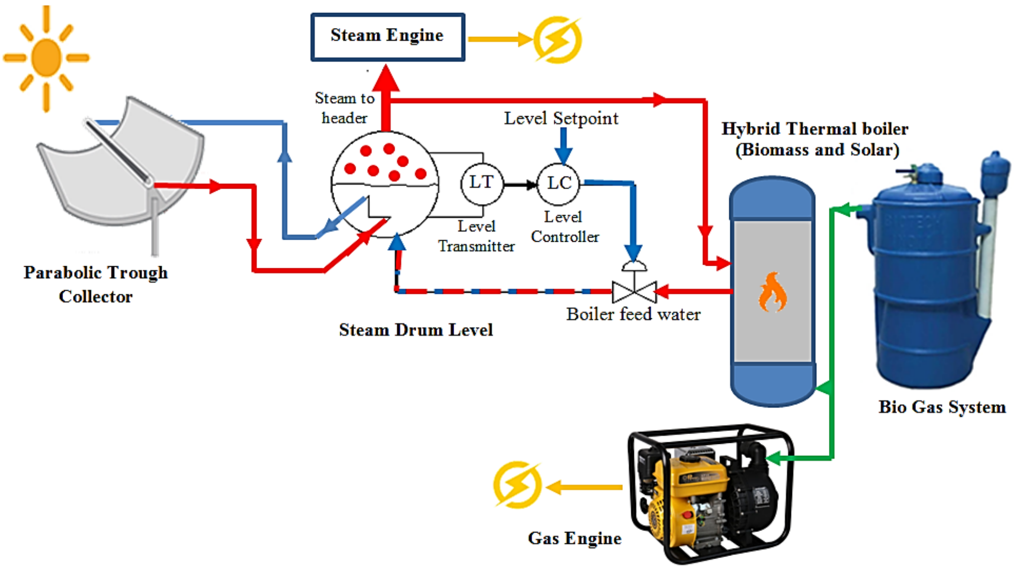


Fig. 3. The Model of hybrid power plant for electric generation

The first section included the solar collector system (CSP) with dimensions (2.5 m^2) and up to 300 W. It calculated the design and analyzed mathematical specifications for a project, "Trough parabolic solar collectors TPC" [5]. It has been adopted in the new system and the results were very similar to the current work. The second one has a water tube steam drum with an inexpensive design (compact, with a simple structure) and an uncomplicated tube replacement and is well suited for industrial use.

Therefore, the mass flow rates will be different because it is mixing with the absorber, such as water (strong and weak) solution flowing. In addition, this part includes another device hybrid thermal boiler (Biomass and Solar). Finally, the third part of the proposed system was done through a practical experiment.

This gas comprises the biogas system that involves methane 50-70%, carbon dioxide (20-25%), and hydrogen sulphide and nitrogen [19]. The product gas is environmentally friendly and non-toxic, and colourless. The thermal value of the gas produced ranges from 3170 to 6625 kcal / m^3 [20]. This device's waste is considered a clean animal fertilizer free from diseased microbes, worms, and parasites.

The flowchart illustrates the steps of the work as shown in Figure 4 below.

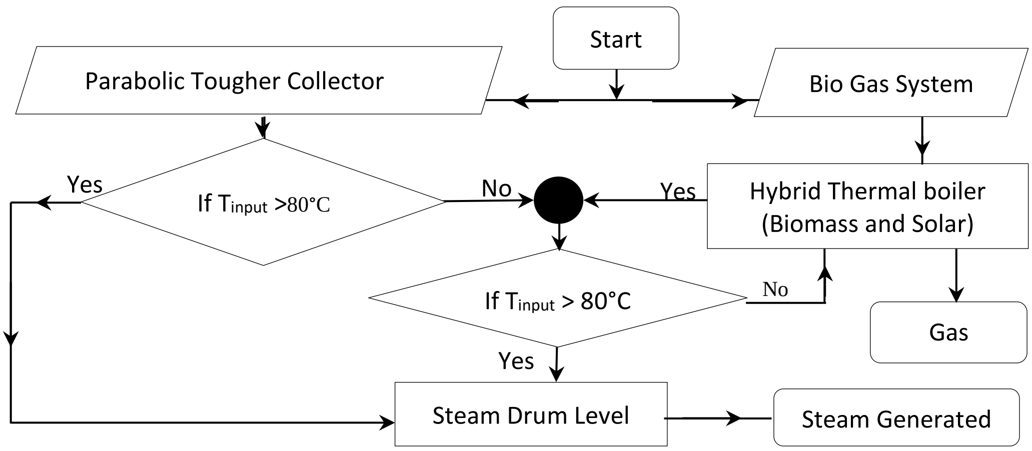


Fig. 4. The model (flowchart)

This model converts over 9,625,105.3 T of waste annually to methane gas and then merges them with the solar collector. This provides the highest percentage of the generated heat economically and at low costs compared with similar energy production sources.

The model predicts it to bring significant revenues and cease the import of electric power [5]. The payback period has been between 5 to 10 years. However, the initial costs are relatively high. In contrast, maintenance and operating costs are lower, and they get very high profits that cover these costs and allow development [21].

4. Methods

This study presents a realistic view of the potential of electricity production from power plants to identify the technical and economic benefits of hybrid biomass energy systems. Figure 6 shows how successful this technique is in steam boilers. Kazem and Chaichan [22] explains that it is easy to calculate the economic evaluation of power plants and develop the proposed system by using the below

i. Three power-generating circuits include thermal oil, the (ORC) Organic Rankine Cycle and the client water [23].
ii. The thermal oil circuit transfers part of the biomass combustion gases' energy into the ORC fluid.

4.1 Mathematical Style for Proposed Model

This section briefly describes various parameters considered in the proposed model's results and calculation results. One example of the feasibility of using these projects in Iraq is the landfill of Al-Nahrawan which can have between 75000 to 100000 Tons/day of various types of waste.

i. The types concluded 34% food waste, 20% paper, 18% plastic products, 11% glass, 11% minerals, and 6% tree and horticultural waste [23].
ii. 60% of this waste can be reused or recycled (such as paper, glass, plastics, and metals), and the rest of it can be a source of fuel and energy by direct burning in waste-derived fuel.
iii. The remaining portion (40%) of the waste (food and plant residues) can be a source of biogas energy through a special treatment to produce (methane).

This work estimated the annual fuel production of methane. Depending on building a model of accounts and assuming, the system operates with an efficiency of up to 40%. It is possible to produce 0.3 m^3 of methane from the digestive system's fermentation process for the proposed system [24]. This system produces about 120 m^3 of methane gas. Methane contains (50-55 MJ/kg) heat from combustion burned or 39.8 MJ /m^3, as shown below [24]:

$$CH_4+2O_2 \rightarrow CO_2+2H_2O$$

$$16u+2\times2\times16u=44u+2\times18u$$
$$16u+64u=44u+36u$$

$$1kgCH_4+4kgO_2 \rightarrow 2.75kgCO_2+2.25kgH_2O+55.6MJ$$

Based on this ratio, energy generated from this landfill was calculated at 1326.6 kWh, representing the energy used to generate electricity from only one landfill out of the 300 landfill sites throughout Iraq.

Based on that, electrical power can be got 38.5 MW/h to determine the specifications of the proposed biomass system and to calculate the amount of thermal energy produced for the proposed model. However, the difference between the TPC and the full load required is calculated [25]. Table 3 below explains the terminology of Organic Compounds used in chemical equations.

Table 3
Nomenclature of Organic Compounds

Number of compounds	Compound Formula	Compound Name	Stem used in naming
1	CH_4	methane	meth-
2	O_2	Oxygen	ox-
3	CO_2	Carbon dioxide	cobalt (II)-oxide
4	H_2O	water	aqua
5	H_2S	hydrosulfuric acid	hydro-(steam)-ic-acid
6	CH_3COOH	ethanoic acid	Carboxylic acid (-oic acid)
7	H_2	hydrogen	hydro-

Eq. (1) explains how much needs for auxiliary fuel ($\dot{m}$) to be generated by the biomass system [14].

$$\dot{m} = \frac{\dot{Q}_{fl} - \dot{Q}_{sf}}{\zeta_{TPC} * LHV_f} \tag{1}$$

where
$\dot{Q}_{fl}$: amount of heat needed to produce (full / load);
$\dot{Q}_{sf}$: amount of heat collected in the TPC;
ζ_{TPC}: efficiency of the extra heating system (biomass) equal 80 %;
LHV_f: lower heating value of the fuel for Biomass is equal (2800 kcal kg^{-1}).

On the other hand, Eq. (2) shows the calculation of fuel consumption for biogas generator [13,15]

$$F = F_0 Y_{gen} + F_1 P_{gen} \tag{2}$$

where
F: fuel consumption (kg/h/kW);
F_0: refers to the fuel curve intercept coefficient (kg/h/kW rated);
F_1: fuel curve slope (kg/h/kW);
Y_{gen}: refers to the rated capacity of the Gas engine in (kW);
P_{gen}: electrical output of the generator by using the ideal gas law.

The pressure value generated in the biogas unit is found Eq. (3) [13-15,25]

$$PV=mRT \tag{3}$$

where
P: the gas pressure (kPa), and the values are shown in Figure 10;

V: equal (100 L);
N: equal 1.339 moll;
R: equal 0.5182 kJ/(kg.k) ;
m: the molar mass, equal 16.043 kg/kmol;
N: a CH_4, a=Volume of CH_4 gas for 0.1 m^3;
m: amount of Fermented Material;
T: the temperature (°C) inside the biomass project is shown in Figure 9.

0.3 is the amount of methane it produces from 1 m^3, 1 moll = 22.4 L=0.1 m^3 × 0.3 =0.03 m^3/day from CH_4, a=30 L/day then a=1.339 moll from CH_4, and m= (16.043 kg/kmol × 1.339 moll) =21.482 kg. Through the above, it is possible to calculate the amount of energy learned from this unit by using Eq. (4) [26]

$$E = H_b \times V_b \times \zeta \tag{4}$$

where
E: the energy learned from the unit (MJ);
H_b: the combustion temperature of the volume unit of gas (about 20 MJ/m^3);
V_b: the biogas size (m^3);
η: 45% if the gas produced from the biogas unit for heat the boiler;
E: 20 MJ/m^3×0.1 m^3× 0.45.

E=0.8 MJ as Energy = 800 kJ =33.33 kJ/h on the basis that 1 kW/h electricity =3600 kJ heat energy, and So (33.33kJ/h)/ (3600 kJ) =9.259×10^{-3}) kW/h. To calculate the required loads of hot water (to generate steam). By finding the daily energy load and the temperature for heating can be determined from the equation below [13].

$$P = M \times C(T_{hot} - T_{could}) \tag{5}$$

where
P: daily load of energy Kwh/day;
M: daily mass of water kg/day, kg/gallon;
C: the specific heat of water = 0.0001667 kwh/kg°C;
T_{hot}: the required hot water temperature is usually higher than 50°C;
T_{could}: the required cold-water temperature is usually up to 18°C.

This design is considered an economic one because it includes different production methods, leading to a difference in the electric price. Also, it is necessary to calculate the cost of generating electricity (LCOE), estimated at the connection point to the electrical network. Many researchers worked on different models for the LCOE equation. However, all of them depend on Eq. (6), including [12,26]

i. The numerator includes the current net capital, fuel, and operating and maintenance costs associated with energy production.
ii. The denominator includes the sum of the total energy produced in the system's life [24]

$$\mathrm{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} = \frac{(I+F)+(C_f+V)}{E} \tag{6}$$

where
$\mathrm{I_t}$: the investment expenditures in the year, including financing;
$\mathrm{M_t}$: equal the operations and maintenance expenditures in a year;
$\mathrm{F_t}$: represented the fuel expenditures in a year;
$\mathrm{E_t}$: the electricity generation in year t also r is the discount rate, and n is the system's life.

While (C_f and V) are energy-related terms, as they depend on the energy generated by the unit [13]. The relative price of electricity depends on this proposed system’s valuable life, which is calculated over 5 to 10 years. The calculations did not include the costs of storing energy, considering the proposed method works when needed.

4.2 Fabrication Process for the Biomass Model

This experiment uses the anaerobic digestion process and depends on simple steps. Designing and implementing a small biomass unit included four-step biological process stages: hydrolysis steps, acidogenesis, and methanogenesis in the quick reaction. In the storage tank, the leavening bacteria can take hold and generate CO_2 and H_2S with acid synthesis, as shown in Figure 6.

While the pH number majored low commonly < 3 because of acid formation and the period for this operation (25 to 30 days) of fermentation at a temperature of (35 to 50) °C [26]. Iraq has witnessed simple attempts at landfill energy projects which were exemplified by a waste recycle station built in Dhi-Qar province with the possibility of electricity 10 MW by methane. But it is currently a stalled project and Figure 3 expounds on the principal operation that includes the mathematical model of each section in the proposed system [12]. Further, Figure 5 shows the Organic (Rankine Cycle) Hybrid cogeneration power plant.

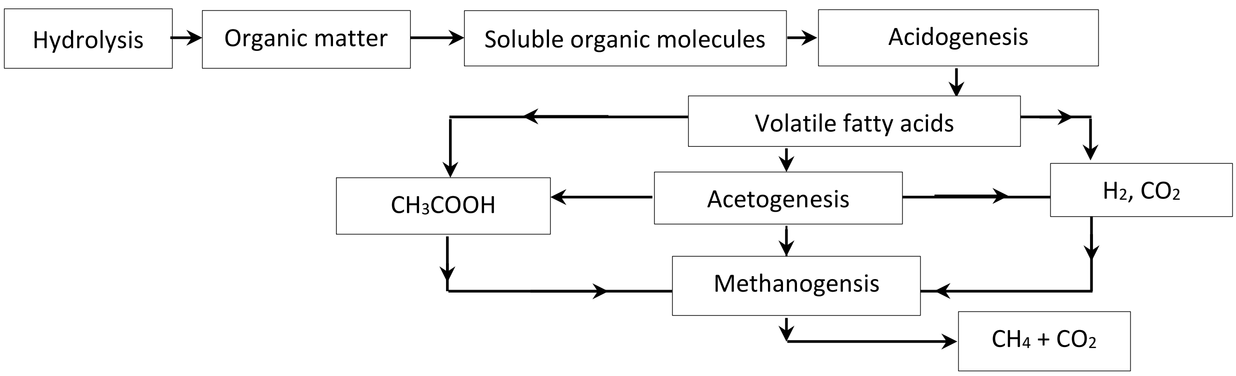


Fig. 5. Organic (Rankine Cycle) Hybrid cogeneration power plant

This experiment has done in the College of Engineering/ Diyala University and used different waste, such as (food waste and tree leaves) mixed with 50% of each kind. The following Table 4 shows the fabrication specifications [27].

Table 4
Fabrication specifications of the biogas generators

Parameters	Design criteria
Average water content	55%
Organic matter	45%
Size of animal manure	% 50 is between (10-80 mm)
Device Dimensions (drum)	(45 d × 75 h) cm, Size up to 0.119 m^3
Total waste quantity	50 kg in one shipment ± % 0.397 (0.1985 kg/day) *
Fermentation unit waste quantity	600 kg/year
Composting time	56 days
Compost quality	Compost temperature, 30-50°C

*Suppose the fermentation of the fermented materials for approximately one month enhanced by 1/30 of the fermented size. So, $0.119\ m^3/30\ day = 0.0039740625\ m^3/day$

The system operates in two temperature ranges: The Mesophyll range is between (25 and 38) °C, and the thermophilic range is between (50-55) °C. In this work, the experimental considerations focused on the ultimate cost of delivered energy in the design and fabrication of the Biomass and they comprise design costs, choices of materials, and cost of labour [28]. Figure 6 shows the natural proposed system, which comprises

i. Tank: Cylindrical shape made of plastic (45 d ×75 h) cm. It is painted black, and the following points characterize the material: stable to corrosion, inexpensive and readily available, and a good insulator.
ii. Measurements unit included: temperature sensor and solar power meter using type Lux Meter.

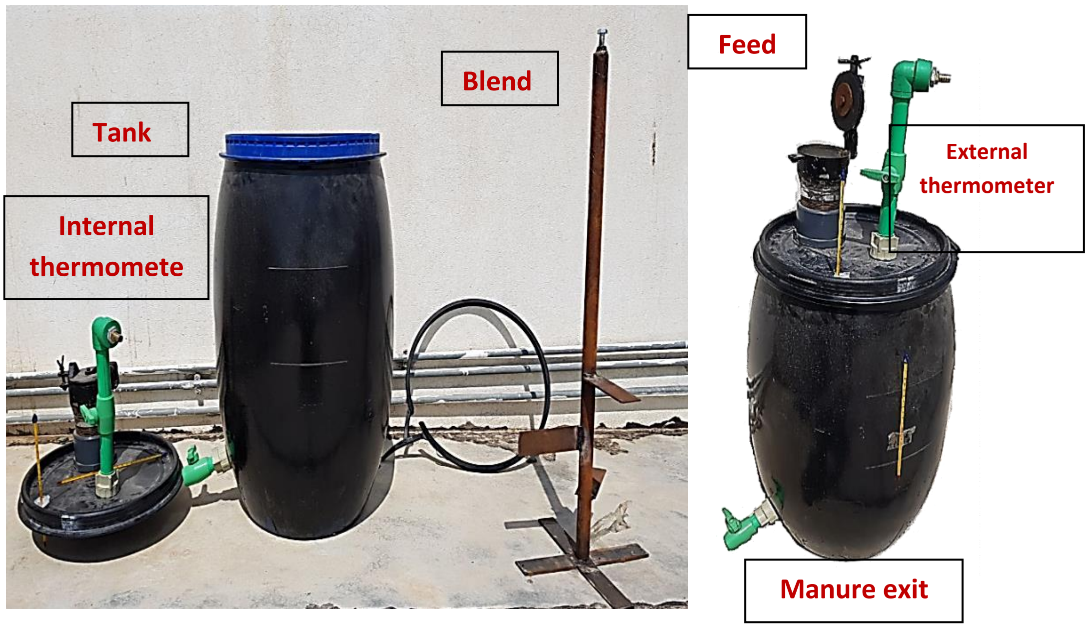


Fig. 6. Biomass project including the barrel that containing the waste food

The highest percentage of biogas production is yielded when the Tin is between (35°C-55°C). Otherwise, methane gas production ceases when the Tin reaches 10 °C, and to solve this problem, especially in the winter, a biogas unit is put under the ground and takes advantage of the temperature stability by increasing the surface depth. The current project works to save energy use in heating, cooling, and electricity generation.

The work also requires determining the technical and economic feasibility and finding a market for this technology to implement, operate and maintain biogas home units on a large scale. Figure 7 shows the practical applications of this design.

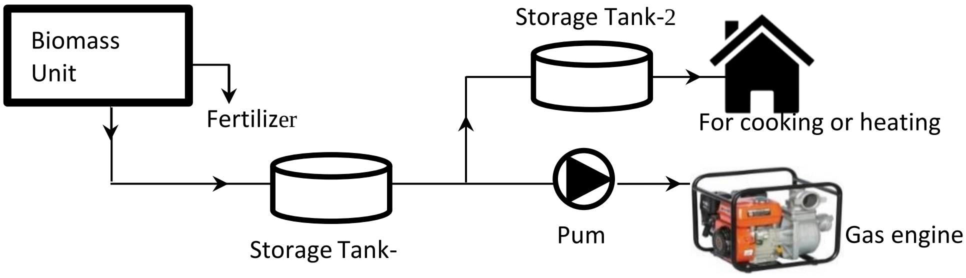


Fig. 7. Scheme for using biomass system

5. Results and Discussions

This experiment has been conducted to assess the influence of three factors: solar radiation, ambient temperature, and pressure on the daily productivity outputs for the biomass system. The interactions between the examined factors and their combined influences on the yield of daily methane gas introduced organic waste in the biogas unit continuously, whether always or at long intervals.

In all cases, the waste mixes with water, according to the percentage in Table 3. It can be fermented aerobically for 20 days before being introduced into the system to simultaneously accelerate the production process. Figure 8 shows the differences between the temperatures measured inside the system in April and May of the same year.

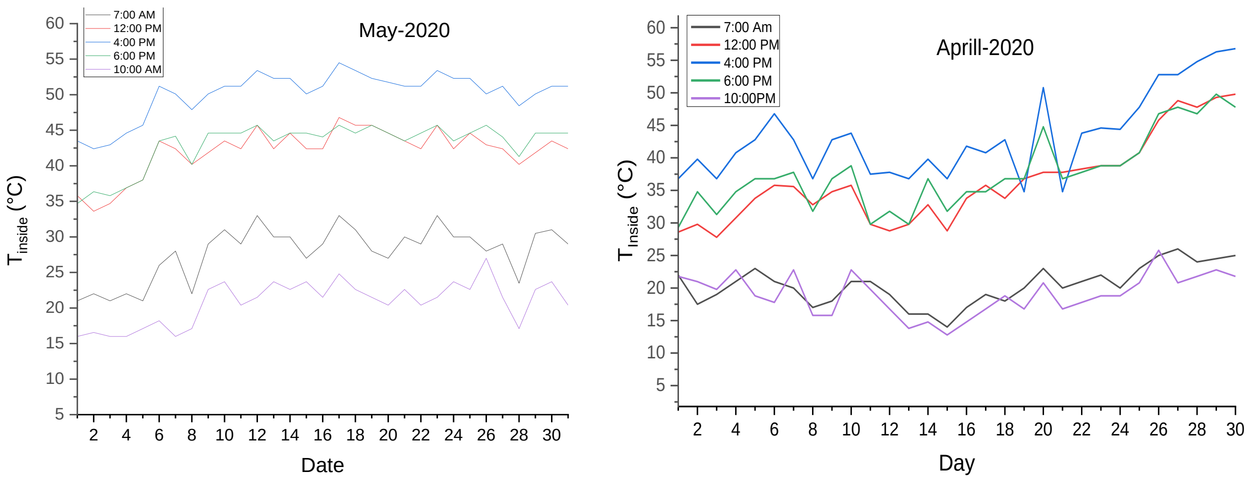


Fig. 8. Differentiate temperature inside the biomass project in April and May 2020

Figure 9 and Figure 10 express the difference between the estimated pressure during the experiment.

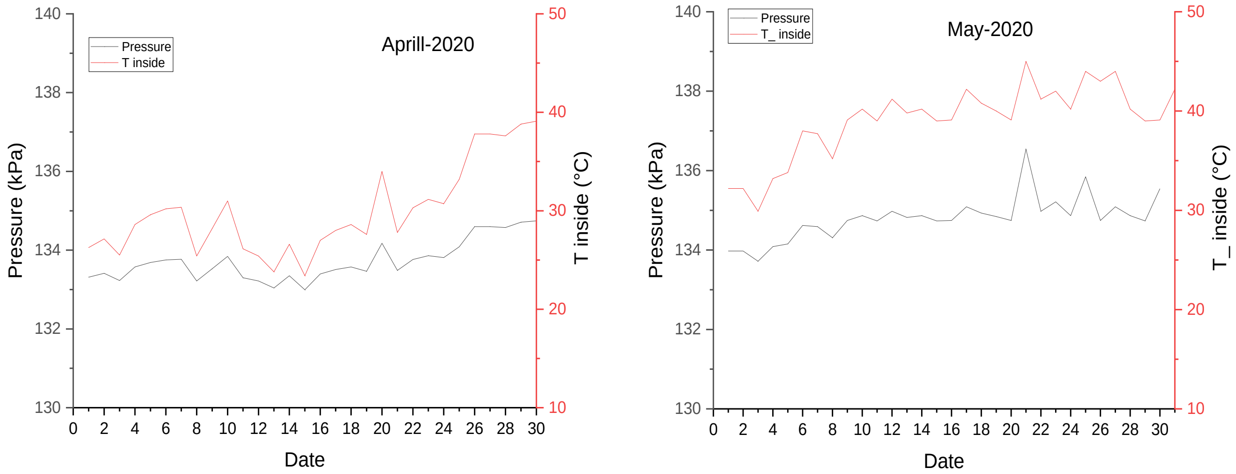


Fig. 9. Amount of gauge pressure inside biomass project

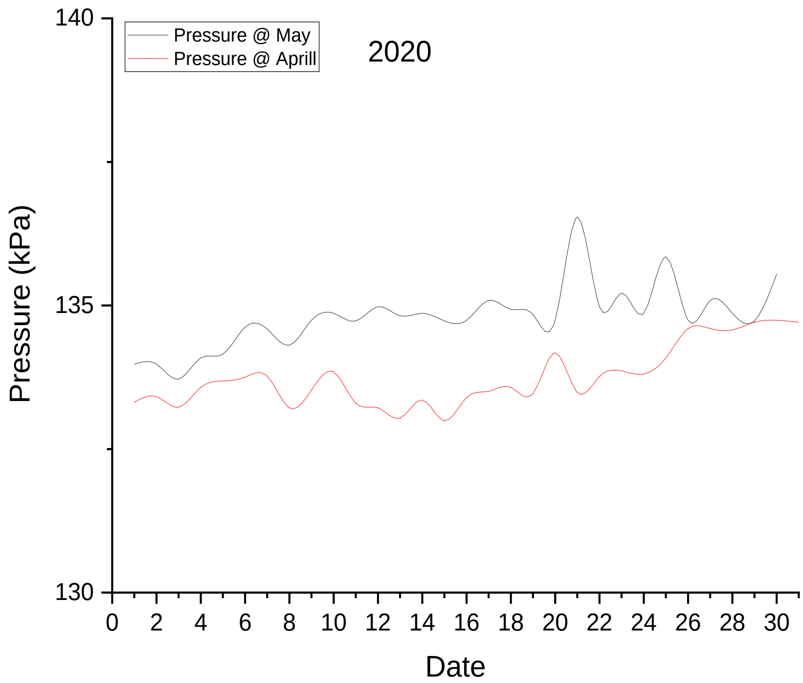


Fig. 10. The variation ratio of gauge pressure in April and May 2020

Eq. (4) shows that the amount of energy harvested is suitable and reaches (0.02975 kwh). This quantity increases with the system's volume relative to the heat required. It is clear to researchers that the Iraqi government has yet to solve this problem or work on it. All that is because of oil. The disadvantage of this problem is environmental pollution because of the need for more landfilling of waste. Acquire renewable energy after educating the community on separating and recycling waste.

While Eq. (8) illustrates that the amount of energy harvested is suitable and reaches (0.02975 kwh), this quantity increases with the system's volume in proportion to the required ratio of heat. It is clear to researchers that the Iraqi government does not solve this problem or work to give importance to it. All that is because of oil. The disadvantage of this problem is environmental pollution because of the lack of landfilling of waste. Acquire renewable energy after educating the community on separating and recycling waste.

The production quantity of this miniature model is shown at 3.9741 litres per fermentation meal. During the experiment, 16 meals were fermented, two meals per week. The required gas ratio for cooking a meal for a person range between 150 and 300 litres of biogas. Approximately 30-40 litres of biogas are required to cook 1 litre of water, 120-140 litres for 0.5 kg of rice and 160-190 litres for 0.5 kg of vegetables. However, this depends on the burner's design and the biogas' methane content.

We must increase the size when we want to improve the production quantity, and Figure 11 exhibits this increase in April from 135 l/month to over 160 l/month in May because of the rising intensity of solar radiation and the high temperature. Moreover, Figure 12 shows the relationship of solar radiation and the pressure of the gas generated.

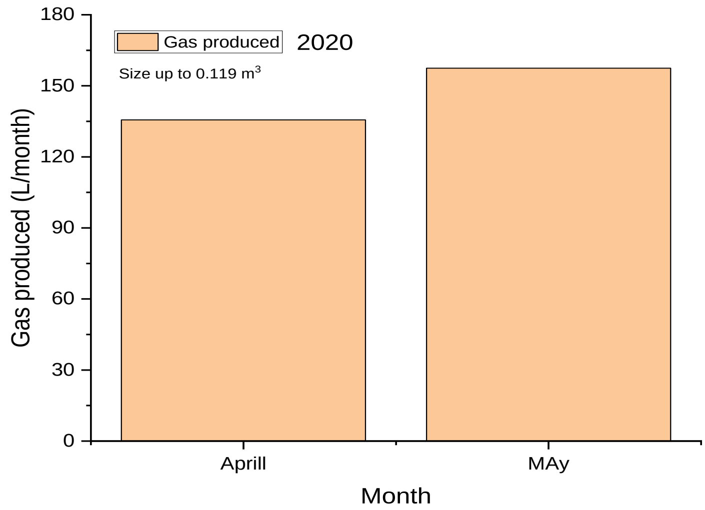


Fig. 11. Gas produced volume

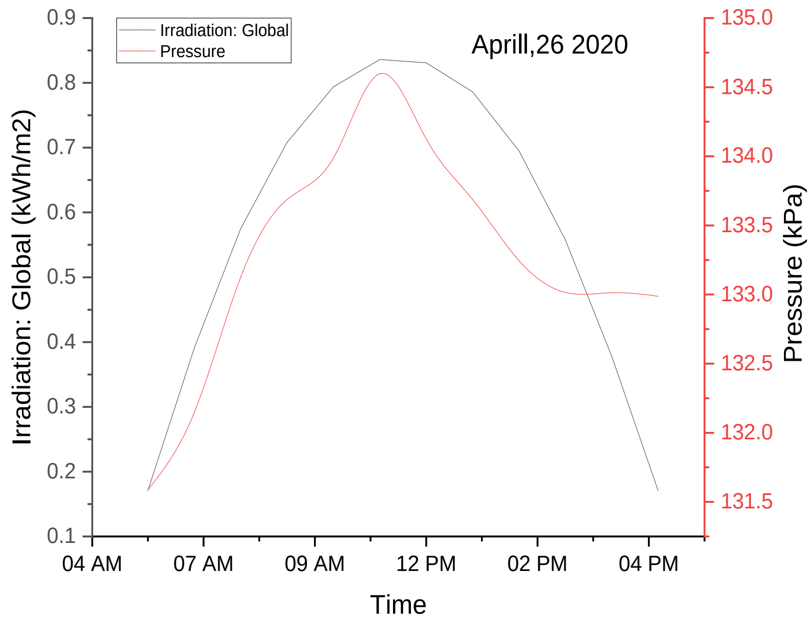


Fig. 12. Relationship of solar radiation and the pressure of the gas generated

6. Conclusions

Iraq can do such projects efficiently and appropriately because it has the possibilities and the resources, such as solar energy and waste, which are available in the middle and the south of Iraq;

this helps to save time and effort, in return producing the required amount of methane. Iraq has over 3000 hours of sunlight per year, and the average solar radiation is about five kw hours per m^3. This study shows the possibility of using different wastes to produce methane gas. This process cost is lower than other types of power sources, and this study produced (38.5 MW/h) of electrical energy. In a hybrid system, the best biogas scheduling is identified and discussed based on scheduling the power generator. During the optimization process, low cost is the study's primary aim.

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