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Technical note

Technical–economical analysis of the Saveh biogas power plant

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Abstract

The resource limitation of fossil fuels and the problems arising from their combustion has led to widespread research on the accessibility of new and renewable energy resources. Solar, wind, thermal and hydro sources, and finally biogas are among these renewable energy resources. But what makes biogas distinct from other renewable energies is its importance in controlling and collecting organic waste material and at the same time producing fertilizer and water for use in agricultural irrigation. Unlike other forms of renewable energy, biogas neither has any geographical limitations and required technology for producing energy and nor is it complex or monopolistic. Considering the ever increasing amount of different types of organic waste materials (about 15 million tonnes) in Iran, working on the control of waste material and biogas production becomes inevitable.

In this paper, biogas and the benefits from its production are discussed, as is the technical-economic analysis of the Saveh biogas power plant as a case study.

Keywords: Biogas; Power plant; Anaerobic digestion; Municipal solid waste (MSW); Slaughter house effluent

1. Introduction

The ever increasing growth in global energy consumption, the limitation of fossil fuels resources on one hand and the destructive effects of consuming these energies on the environment on the other hand, have increased interest all over the world in the use of renewable energy resources, including biogas.

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The increasing amount of organic waste material in both urban and rural communities and also the production of thousands of tonnes of sludge from sewage and wastewater from different agricultural and food industries leads to severe economic and environmental difficulties. There are different treatment processes for organic waste material. In many cities, sometimes the only alternative available for getting rid of waste materials is to either bury them or burn them. In such cases, chemical pollutants are not destroyed, but enter the underground layers and water, soil, plants and air cycles and thus pollute the ecosystem.

On the other hand, if the buried waste materials are not well digested in a municipal solid waste (MSW) landfill by anaerobic micro-organisms, large volumes of methane and carbon dioxide gases enter the atmosphere, which has a climate change impact.

One of the most effective processes for getting rid of organic waste material and at the same time providing much needed energy is anaerobic digestion.

The existence of 15 million tonnes of municipal solid waste [1] and the production of 4.6×10^9 m^3 of urban and industrial sewage (with a collection and burial cost of US$ 225 million) [2] in Iran points to the value of developing biogas technology.

In this anaerobic digestion of organic waste material by different micro-organisms, organic macro-molecules are converted into simpler molecules and the final result is combustible biogas containing about 60–70% methane and 30–40% carbon dioxide depending on feedstock type.

The development of biogas technology would provide part of society's energy need, and a variety of other applications (Fig. 1).

In this paper, the different parts of a biogas power plant are introduced and the Saveh biogas power plant is analyzed.

2. Technical analysis of the Saveh power plant

The city of Saveh, in central Province, 150 km from Tehran, has a population of 120,000. It has a semi-arid climate and the temperature during different seasons of the year fluctuates within the range of -10 to 40 °C.

To establish a biogas power plant, the usable organic resources in Saveh were studied. They were divided into four groups: household garbage, sludge from sewage treatment, slaughterhouse wastewater and sludge from leaching pits [4].

Through statistical studies, separation, sampling, and physical and chemical tests, the quantity and quality specifications of each of the four types of pollutants were determined (Table 1).

After determining the quantity and quality of each pollutant and potential for production of biogas from mixed feed including the above-mentioned pollutants, the existing characteristics of the city anaerobic reactor at 35 °C were investigated using a semi-industrial anaerobic reactor (Fig. 2).

The metal reactor has a volume of 10 m^3. In order to heat up the contents and create suitable heating conditions, it is equipped with an internal coil and a sludge evacuation pump to mix the contents. The reactor has been designed in such a way

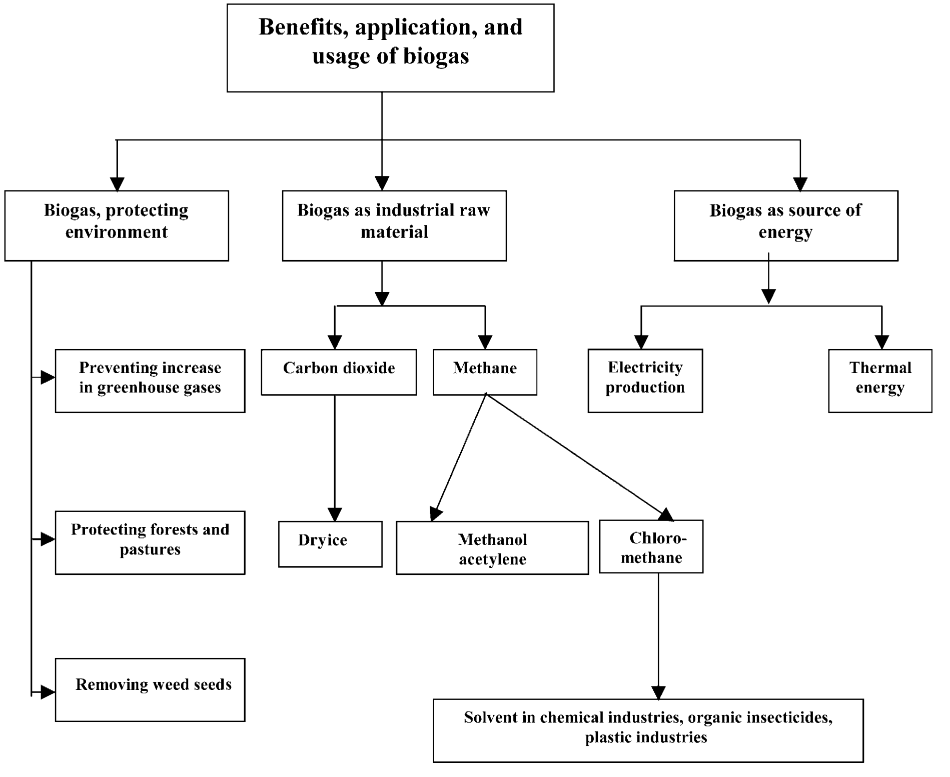

Fig. 1. Benefits, application, and usage of biogas [3].

that it is capable of operating both continually and for batch processes (Fig. 2). In order to study the anaerobic digestion of these feeds on a continuous basis, determining the residence time of the material in the reactor was necessary. Initially, producing gas in the reactor through a batch process was studied. By investigating

Table 1
Specifications of organic waste resources in Saveh

Resource	Parameter		
	Quantity (tonnes)	T.S. (tonnes/day)	V.S. (tonnes/day)
Garbage/day	78.3	–	–
Household garbage/day	58.7	–	–
Organic material of garbage/day	38.2	5.73	4.29
Sludge of sewage treatment/day	27.4	0.274	0.175
Slaughterhouse effluent/day	12	0.061	0.051
Discharged sludge of household wells/day	13.7	0.137	0.084

T.S. (Total solids)
V.S. (Volatile solids)

Fig. 2. Anaerobic metallic digestion reactor with 10 m^3 volume used in biogas assessment test.

the volume of gas produced daily and the speed of production during the batch period, the residence time was determined to be 20 days (Fig. 3) for continuous studies; a 20 day residence period was also agreed upon.

Studies during the continuous loading of combination feed including the four groups of urban pollutants with actual recording in the city of Saveh showed that for each kilogram of total solid input, 500 l of biogas was produced in the anaerobic digestion process. Thus, on the basis of studies carried out in the Saveh biogas power plant, the operation can be summarized as follows (Table 2).

3. Economic, social, and health effects of the Saveh biogas power plant

Since most of the economy of Saveh depends on the export of agricultural products such as pomegranate, grapes, and cantaloupe, the establishment of the biogas power plant provided not only part of the fertilizer needed for agriculture, but also the necessary water for irrigation, which altogether will have a positive effect on the economy.

On the other hand, anaerobic digesters help in controlling bad smell, and flies, thereby providing undeniable health and social effects some of which are summarized as follows.

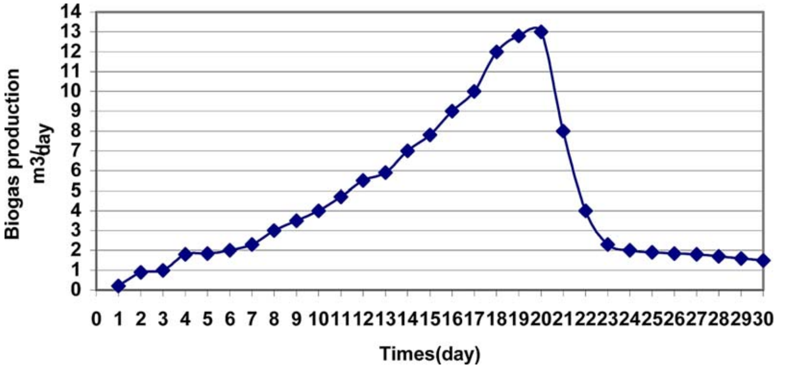

Fig. 3. Biogas production curve in batch loading at 35 °C.

3.1. Economic effects

There are several economic benefits resulting from the biogas plant.

- Treatment of solid waste without long-term follow-up costs usually due to soil and water pollution.
- Reduction of foreign exchange needs:
  - through production of compost to reduce fertilizer, chemical herbicides and pesticides demand
  - through direct utilization of energy produced (biogas/electricity/heat) in the treatment process to reduce fossil energy demand.
- Generation of income through compost and energy sales (biogas/electricity/heat) to the public/public grid.
- Improved soil/agricultural productivity through long-term effects on soil structure and fertility through compost utilization.
- Recovery of material to be recycled or sold to the recycling industry, improving its economic prospects.

Table 2
Summary of operation and technical specifications of the Saveh biogas power plant

1	Amount of biogas produced for every kilogram of dried input/day	500 l/kg of (T.S.) solid
2	Percentage of T.S. in combination feed entering reactor, including four types of pollutants	6.794%
3	Amount of daily input to the power plant	91.3 tonnes/day
4	Amount of total solids as input/day	6202 kg/day
5	The most suitable residence time at 35 °C	20 day
6	Total volume of biogas produced/day	3101 m^3/day
7	Amount of fertilizer produced/day	2500 kg/day
8	Extracted water suitable for agricultural irrigation	31,025 m^3/year

T.S. (Total solids)

- Reduction of landfill space and consequently land costs.
- Application and testing of the most modern treatment scheme for further duplication in Iran.

3.2. Social and health effects

In addition to cost effects are social benefits, including health.

- Creation of employment in the recycling sector.
- Improvement of health and hygiene situation, particularly for women due to their role in households and for people employed or active in the waste sector.
- Improved appearance of the streets and city of Saveh.
- Improvement of the general condition of farmers due to the local availability of soil-improving fertilizer (transport distances, workload, budget).
- Mesophilic treatment of the waste at 35 $^{\circ}$C and intensive composting improves the aspect of the waste and makes application of the final products to land fertilizer possible without health risks.

4. Conclusion

There are a variety of ways to get rid of garbage, but considering the low cost of the anaerobic system in comparison with other processes and the simplicity of its technology, climatic conditions, and the types of components of garbage in Iran, it seems that if priority is given to the utilization of anaerobic systems, then the establishment of biogas power plants can not only provide part of the required energy of the society, enriched fertilizer, and irrigation water, but can also reduce the microbe and chemical pollutants loads and further reduce greenhouse gases. Elimination of smells and harmful insects from the outskirts of the city are among some of the mentionable advantages of utilizing anaerobic digesters in controlling garbage.

Thus, the desirable economic, social, and health effects of the Saveh biogas power plant are incentives that encourage the establishment of larger biogas power plants around larger industrial cities, and this should be taken seriously.

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