Available online at www.sciencedirect.com
ScienceDirect
Renewable and Sustainable Energy Reviews 13 (2009) 248–252
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

Biogas as a sustainable energy source in Nepal: Present status and future challenges

Rajeeb Gautam[a,1], Sumit Baral[b,2], Sunil Herat[c,*]

[a]*Department of Chemical and Biochemical Engineering, University of Western Ontario, London, Ontario, Canada N6A 5B9*
[b]*Information Management and Planning (Research), Nepal Tourism Board, Tourist Service Center, P.O. Box 11018, Bhrikuti Mandap, Kathmandu, Nepal*
[c]*Griffith School of Engineering, Griffith University, Brisbane, Queensland 4111, Australia*

Received 15 June 2007; accepted 6 July 2007

Abstract

Cattle manure, human excreta and agriculture residues are used in anaerobic bioreactors in many parts of the world to produce methane gas, which is used for the purpose of cooking and lighting. Since such waste materials are readily available in farms, rural people of many developing countries have been benefited from this technology. Besides, this technology is cheaper and simpler, thus, gaining popularity throughout the world. Nepal is one of the least developed countries with the vast majority of people involved in subsistence agriculture. The use of biogas technology in Nepal has benefited the country in improving health, environment, economy and energy conservation. In this paper, we present the state of the biogas sector in Nepal.

Keywords: Biogas; Methane; Nepal; Cattle manure; Bioenergy

Contents

*Corresponding author. Tel.: +61 7 3735 6682; fax: +61 7 3735 7459.
E-mail addresses: rgautam@uwo.ca (R. Gautam), sbaral@ntb.org.np (S. Baral), s.herat@griffith.edu.au (S. Herat).
[1]Tel.: +1 519 661 2111x81290; fax: +1 519 661 3498.
[2]Tel.: +977 1 256909/256229/256230x124; fax: +977 1 256910.

1364-0321/$ - see front matter
doi:10.1016/j.rser.2007.07.006

1. Introduction and background

Methane (CH_4) gas generated using biodegradable substances such as vegetable wastes, agriculture residues, wastewater, cattle manure, human excreta, etc. in anaerobic reactors is popularly known as biogas. In agriculture-based countries around the world, biogas is produced in household reactors known as biogas digesters to provide energy for lighting and cooking. Millions of people, especially farmers, have benefited from this technology and its popularity is ever growing. In this paper, we present the information pertaining to the development of the biogas sector in Nepal, where more than 80% of people live on subsistence agriculture in rural areas. In particular, the history of biogas implementation, benefits associated with this technology, future potential and challenges are discussed. The information presented in this paper will be helpful not only to different stakeholders involved in the biogas sector in Nepal but also to similar other countries around the world, which face challenges for its efficient implementation.

1.1. Geography and demography

Nepal is a landlocked country with a total area of 147,181 km^2. Nepal shares its borders with China in the north and India in the east, west and south. The geographical structure of Nepal resembles a rectangle with a dimension of approximately 885 km (east–west) × 200 km (north–south). Within this relatively short width, the country's cascading landscape rises from almost the sea level in the south to the world's highest altitude (i.e. Mt. Everest). Furthermore, the climate also changes from tundra to tropical from north to south.

Population of Nepal has been estimated at 23 million, which is increasing at an annual rate of 2.25% according to the 2001 census. It is also estimated that only about 14% of the total population resides in the urban centers while the rest 86% resides in the rural areas. Number of household has been estimated at 4.25 million with an average of 5.44 persons per household [1]. Table 1 provides a summary of Nepal's geographical and demographical features.

1.2. Economy

Nepal's economy is driven mainly by the agriculture sector which accounts for almost 85% of human resource involvement and 39% of gross domestic product (GDP). Industrial and service sector GDPs account for 7.7% and 53.3%, respectively [2]. Industrial sector mainly comprises processing of agricultural products such as jute, tobacco, sugarcane, grain, dairy products, etc. Average per capita GDP is estimated at US$237, while 38% of the population still remains below the poverty level of US$1 per day [2]. Rural sector is mostly remote, which lacks basic infrastructure such as running water, electricity, transportation, health and education. Since the majority of the population is involved in the agriculture sector, livestock such as cattle, poultry, goat, etc. are domesticated widely.

1.3. Energy usage

The total energy consumption for Nepal was reported at 8616 tons of oil equivalent (TOE) in 2005 [3]. Almost 88% of this energy is obtained from traditional energy sources such as firewood, agriculture residues (corn stalks, rice chaff, etc.), and sun-dried cattle dung cakes. Of the total energy consumption in 2005, the share of household energy use was 90.3%, followed by industrial (3.5%), commercial (1.6%), agriculture (0.8%) and other (0.2%) [3]. The widespread use of such traditional forms of energy resources has adversely impacted the country's environment, people's health and economy in many ways [4].

1.4. Environment and human health problems

Excessive exploitation of forest wood in all parts of the country has caused deforestation. Deforestation has been linked to many other problems such as soil erosion, loss of cultivable land, fluctuating and unpredictable river flow patterns, flash floods, etc. in almost every part of the country [5]. Similarly, the use of agriculture residues and cattle dung cakes in inefficient smoke causing cooking stoves in the indoor environment has caused respiratory-related illnesses in adults, children and infants [6,7]. Time spent in collecting forest firewood also accounts for a major portion of daily labor and many health-related ailments that include backache, severe fatigue, head and neck pain, fall injury, etc. [8] among women in rural communities. Due to deforestation, the travel time has increased as forest reserves have receded farther away from communities.

1.5. Emergence and development of the biogas sector

The technology of the generation of methane from the anaerobic fermentation of cattle manure, human excreta, wastewater, etc. gained popularity in the neighboring India around 1950 [9]. Farmers in India used the biogas

Table 1
Geographical features of Nepal

Land type	Altitude[a]	Area (km^2)	% Total area	Width[b] (km)	Climate type	Population (% of total)
Himalayas	4877–8850	51,817	35	25–60	Tundra	7
Mountain	610–4877	61,345	42	60–80	Temperate	44
Southern plain	100–610	34,019	23	25–40	Subtropical	49

[a]m above sea level.
[b]North–south (source: adapted from [21]).

technology to generate cheap fuel and tackle the litter problem. Since Nepal shares many socioeconomic and geographic similarities with India, the development of the biogas sector in Nepal was greatly influenced by the development of the biogas sector in India.

Different historical accounts suggest that the first biogas plant in Nepal was built in 1955 in the capital city (Kathmandu). It was a demonstration model that was mainly constructed to show the potential of biomass to generate energy. A chronology of biogas development events in Nepal is shown in Table 2. Similarly, Fig. 1 shows the number of biogas plants installed between 1982 and 2003 in Nepal. As shown in this figure, more than 111,000 biogas plants have been installed in Nepal.

The development of the biogas sector in Nepal has been possible due to the joint effort of different stakeholders. In this regard, a pivotal role has been played by Biogas Support Program (BSP), an independent non-profit organization, through the financial assistance provided by the Netherlands [10].

Several factors have been attributed to the development of Nepal's biogas sector, which include: (i) rising level of awareness among the rural people about the benefit of the biogas technology; (ii) energy, health and environmental costs associated with the use of traditional forms of energy; (iii) inaccessible and underdeveloped rural communities with little or no supply of fossil fuels; (iv) easily available organic substrates in the form of farm waste that could be used in bioreactors; (v) freely available technology without any intellectual property right issues; (vi) readily available raw materials to construct biogas reactors; and (vii) availability of loan and subsidy from the government.

2. Biogas digester design in Nepal

Many different designs of biogas digesters are available both in small and large scale operations throughout the world [11–13]. In the context of Nepal, fixed dome belowground biogas plants have been used almost universally. This type of model was first introduced in 1990, which was a modification of the Chinese [14] and Indian [11] fixed dome models. A typical model used in Nepal is shown in Fig. 2. This design exists in several sizes ranging from 4 to 20 m^3. This type of design can be constructed almost entirely using locally available materials such as clay, brick, cement, bamboo, wooden supports, etc. [15].

Table 2
Chronology of biogas development in Nepal

Year	Biogas related activity
1955	First demonstration model
1974	Department of Agriculture implemented a program to construct 250 biogas plants, interest free loan was provided
1977	Biogas and Agriculture Equipment Development P. Ltd. was established for the first time
1980	Gobar Gas and Agricultural Equipment Development Company (GGC) modified the Chinese fixed dome model
1990	The GGC modified fixed dome model accepted as a suitable model for Nepal
1991	Biogas Support Program (BSP), an independent organization, was established to oversee Nepal's biogas sector
1991–present	BSP continues to play an important role in biogas sector. Approximately, 140,000 biogas plants have been installed all over the country. Numerous private sector businesses have joined the market. Micro credit financing has gained popularity

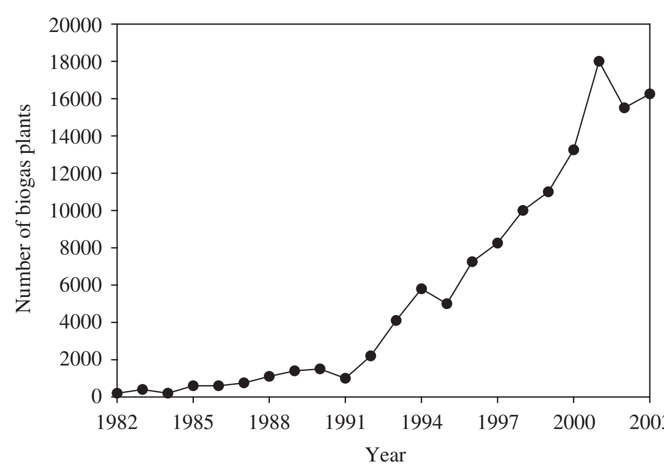

Fig. 1. Number of biogas digesters installed in Nepal.

3. Benefits from biogas

3.1. Human benefits

3.1.1. Health

Some of the health-related benefits achieved from the implementation of biogas plants in Nepal include: reduced

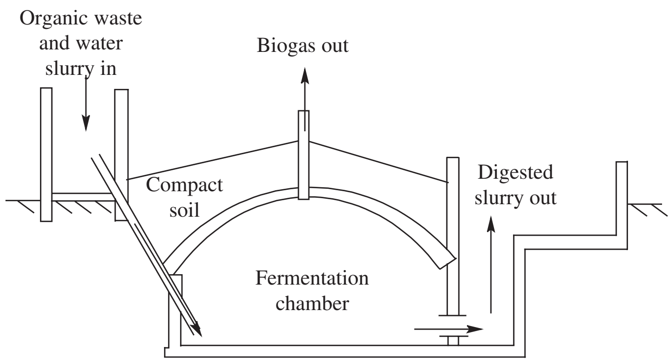

Fig. 2. A typical model of fixed dome biogas plant used in Nepal.

smoke exposure in the indoor environment, reduced acute respiratory infections on population of all ages, improved infant mortality rates, reduced eye ailments, reduced concentrations of carbon monoxide, formaldehyde and suspended particles in indoor environments [16].

3.1.2. Hygiene

Due to the lack of wastewater collection and treatment infrastructures in rural Nepal, unmanaged human excreta and wastewater are major problems. Contagious diseases such as diarrhea, cholera and tuberculosis, etc. are common occurrences in rural areas. However, the use of biogas digesters has helped improve the hygiene situation. It is estimated that 77,000 households in rural Nepal have now toilets that are connected to biogas plants [10].

3.1.3. Education

There is a severe shortage of energy for lighting in the rural areas. This makes it impossible for children to be involved in any education-related activities in the evening after sunset. Establishment of biogas digesters has provided energy for lighting in more than 20,000 households in rural areas [17]. This has provided a convenient means for reading or study even in the dark.

3.1.4. Employment generation

Approximately 11,000 people are employed in the biogas sector. The breakdown is as follows: technical 6000, administrative/financial 2700, local promoters 800, and the rest suppliers. The spin-off effect of employment in the biogas sector has been estimated to provide employment for around additional 65,000 people nationwide [10].

3.1.5. Gender benefits

Since women and female children are involved in collecting the firewood, they have been able to reduce up to 3 h everyday that they used to spend in collecting firewood [18]. This is equivalent to a saving of more than 35,000 woman hours per annum based on the installation of 111,000 biogas plants in the country [17]. Since the burning of biogas is not associated with the deposition of soot particles on the surface of cooking pots, it has also led to the saving of water consumption and time required to wash these utensils.

3.2. Economic and environmental benefits

3.2.1. Reduction in fuelwood consumption

According to a recent estimate, almost 10,000 ha of the forest cover in the Southern plain region in Nepal was lost due to fuelwood collection activities in 2004 [19]. However, the installation of biogas plants has helped protect the forest. For instance, there is an annual saving of 2 tons of fuelwood per household that has installed a biogas plant [17]. This means that there is a nationwide saving of more than 200,000 tons of fuelwood per annum.

3.2.2. Reduction in the use of agriculture residues in stoves

Prior to the installation of biogas plants, vast quantities of agriculture residues were used in inefficient cooking stoves, which caused a widespread indoor smoke pollution. Since 2.7 kg of agriculture residues are used as substrate in the biogas digesters per household (110,000 tons nationwide), they are converted to the methane gas, which is a very efficient form of energy without smoke and soot particles [17].

3.2.3. Reduction in the use of dried cattle dung in inefficient stoves

In average, 0.7 kg of cattle dung is saved from being dried and burnt in inefficient cooking stoves in every household. As in the case of agricultural residues, the cattle manure is converted to an efficient energy in the form of methane gas [20].

3.2.4. Reduction in kerosene use

Kerosene is widely used in Nepal for cooking and lighting purposes. Due to the installation of biogas plants, the use of kerosene has been reduced by almost 7.7 million liters per annum in Nepal [20]. Since petroleum product is imported using hard earned foreign currency, the reduced use of kerosene has saved approximately US$2.1 million per annum.

3.2.5. Reduction in chemical fertilizer use

Along with methane gas, biogas digester produces organic fertilizer that is high in nitrogen, potassium and phosphorus contents. This organic form of fertilizer can be used in farmlands as an alternative to chemical fertilizers. Chemical fertilizers are usually imported in Nepal. It has been estimated that there is an annual saving of 4329 tons nitrogen, 2109 tons phosphorous and 4329 kg potassium due to the installation of biogas digesters. This translates into a annual saving of almost US$300,000 [20].

4. Opportunities and challenges

Based on the nationwide cattle population, it has been estimated that approximately 1.3 million biogas plants can be installed in Nepal [15]. However, only about 111,000 plants have been installed throughout the country at present [10]. This shows that only about 9% of the total biogas potential has been utilized in Nepal. If the full potential can be achieved, the benefits mentioned in the foregoing section can be increased tremendously.

Nepal faces several challenges in the biogas sector listed as follows:

- *Cold temperature*: In many hilly areas of Nepal, the temperature drops below 10 °C, which is not suitable for biogas production. Due to this, the biogas technology has been found to be less feasible in hilly areas. Therefore, more research needs to be done in increasing the efficiency of biogas production in colder regions.
- *Private sector participation*: At present there are more than 30 private companies in Nepal that are involved with the biogas sector. However, only eight of these companies are capable of installing more than 500 biogas plants per year because they are weak financially.
- *Remote locations*: Remote locations of many villages in Nepal make it difficult for efficient implementation of biogas plants.
- *Mosquitoes*: Many biogas plant users have complained about the prevalence of increased mosquitoes after the installation of biogas plants. This has also caused adverse publicity of biogas plants among people.

It is essential to find out solutions to these challenges so that more biogas plants can be installed and more of its potential can be utilized.

5. Conclusions

The present state of methane gas production in Nepal using cattle manure, human excreta and vegetable wastes in anaerobic bioreactors was discussed in this paper. The methane gas is widely used to substitute the traditional forms of energy sources such as cattle dung cakes, fuelwood, agriculture residues, etc. This has greatly helped the nation in many ways such as income generation, litter management, life style improvement and cost savings. Although the biogas sector has helped the country in many ways, only 9% of the country's biogas potential has been realized. Much work needs to be done to reach out to the people living in the remote areas and to provide the necessary financial and technical support to them. Also, the problems associated with the generation of methane in colder regions need to be addressed in order to make this technology more versatile throughout the country.

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