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A review on biogas technology and its contributions to sustainable rural livelihood in Ethiopia

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ABSTRACT

Biogas technology has uneven dissemination over the globe. The technology is at its infant stage of development and dissemination in many developing countries while China has the largest implementation record. The principal factors controlling its dissemination include: policies and institutions, financial constraint, subsidies, availability of inputs, awareness about the technology, consumers' considerations, and success stories about the technology. However, biogas technology is a multipurpose technology which assists in addressing economic, health, social and environmental problems simultaneously. Thus, development and dissemination of the technology certainly minimize energy poverty and improve peoples' status in the energy ladder. In line with this, Ethiopia has completed implementing the first phase (2009–2013) of its National Biogas Programme and has started implementing its second phase. During the first phase, it was able to disseminate 57.6% the total 14,000 domestic biogas plants planned for the period. Though the technology was introduced about five decades ago into the country, biogas installations constructed prior to the establishment of the National Biogas Programme were having varied digester models, lacked standards and central coordination and their entire number was not more than 1000. This paper reviews the status of dissemination of household biogas technology, factors influencing the dissemination of the technology, benefits of the technology at global scales, energy resources, consumption patterns and brief account of the technology at national scale-Ethiopia.

Contents

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1. Introduction

Energy is a critical requirement for economic development and specifically to improve living conditions. It influences all aspects of human welfare. However, the majority of the people in developing countries have no access to reliable and affordable domestic energy sources. Even worse, access to modern fuels is much lower for rural people than the urban counterpart. Hence, Ethiopia, despite its endowments with huge potentials of renewable energy sources such as hydropower, wind, geothermal, and biofuels, suffers from a severe domestic energy problem. This problem can be manifested, inter alia, by the relatively very low per capita energy consumption and the dominance of traditional biomass fuel use. More terribly, the growing scarcity of wood-fuel force rural households to increasingly rely on more inferior fuels such as cow dung and crop residues. Hence, energy transition has been occurring in the reverse direction in Ethiopia and a bottom line of the energy ladder has already been reached in some areas.

To address the problem of energy poverty and the associated socio-economic and environmental challenges, development and dissemination of household biogas plants appears to be one of the promising areas of interventions. Unlike in emerging economies like China and India where biogas technology is well developed, the technology is still at its infant stage of development and dissemination in Ethiopia. Despite the relatively long time (about 5 decades ago) since its introduction, the country only recently completed implementing the first phase (2009–2013) of its National Biogas Programme (NBP) and has started implementing the second phase. In the first phase, out of the 14,000 domestic biogas plants planned for the period [1], only 57.6% were able to be installed [2]. Hence, at this juncture, it is reasonable to raise two questions. What are the factors that influence the pace of dissemination of biogas technology in Ethiopia and to what extent the already disseminated biogas plants have impacted the users, non-user neighbors and the environment as a whole? These research questions need to be answered to facilitate effective implementation of the renewable energy technology transfer. Therefore, assessment of the factors influencing the pace of biogas dissemination and the cumulative impacts of biogas installations on sustainable rural livelihood remains to be a crucial area of research. This review paper is believed to have a wider application and implications to policy makers and professionals working in renewable energy development and transfer.

Section 2 of the paper reviews the current global dissemination status, factors controlling its dissemination and the major benefits of the technology. Section 3 describes the concept of the energy ladder and the status of developing countries in the energy ladder with emphasis to Sub-Saharan Africa countries. Section 4 presents the results part describing the potentials of the energy resources, energy consumption patterns as well as brief account of biogas technology in Ethiopia. Section 5 describes the discussions based on the results; and Section 6 draws conclusions.

2. Global overview of biogas technology: Disseminations and benefits

2.1. Disseminations of biogas technology

2.1.1. Current dissemination status

The beginning of anaerobic fermentation particularly for the treatment of organic wastes traced back to the period before the Birth of Christ [3]. However, it was in 1895 for the first time that biogas generation from a "carefully designed" sewage treatment installation began providing street light in Exter in England. People's interest to use biogas as fuel grew particularly during the Second World War. In 1940s, French scholars showed particular concern to the development of biogas technology and as a result a large numbers of biogas installations were built in its colonies. It was also during this period that fuel famished French and Germany commenced using biogas to fuel vehicles and tractors. With the end of the war, a number of countries including England, United States of America, Canada, Russia, Japan, China, Kenya, Uganda, South Africa, New Zealand, and India became more interested in the use of biogas [4].

Nevertheless, interest on the utilization of biogas diminished considerably since about the mid 1950s mainly due to the low-priced availability of fossil fuels. Consequently, nearly all biogas installations were abandoned [3,4].

However, interest on biogas generation revived once again following the global oil shocks of the 1973 together with the mounting concern for environmental protection in the decade [3,4]. Thus, since this decade onwards, the use and dissemination of biogas technology has continued in both developed and developing countries. Indeed, the focus on scales of biogas generation differs between developed and developing countries. Developed countries focus dominantly on large scale biogas installations for combined heat and power generation whereas the primary focus of developing countries is on the construction of small scale biogas digesters that particularly generate heat for cooking [5].

Among the developed world, Germany is by far the leading country in biogas generation. In 2010, it had about 5800 large scale biogas installations from which it generated 2300 MW of electricity. Whereas United States of America possessed merely 160 anaerobic digesters from which it generated 57.1 MW of electricity [6]. In this same year, Europe's total biogas production was 10.9Mtoe from which Germany accounted 61% while United Kingdom, the second country in the hierarchy, constituted only about 16.5% [7]. Germany has also a grand plan to raise the number of biogas projects to 43,000 up to 2020 [3]. Next to Germany and United Kingdom, other top biogas producing countries in Europe encompass: Italy, France, the Netherlands, Czech Republic, Spain and Austria [8].

Of the developing countries, China outstandingly leads the world in the number of domestic biogas plants. By the end of 2010, the total number of domestic biogas installations reached 40 million from which the country produced 15.4 billion cubic meter biogas annually [9]. By the end of 2011, the number of domestic biogas installations grew to 41.68 million [10]. In addition, the country's grand plan of building 6 million new domestic biogas plants every year in the 11th five years plan has continued to be implemented in the ongoing 12th Five Years Plan (2011–2015) of Rural Biogas Construction [11,12]. Thus, as shown in Fig. 1, since about 1982, there has been a continuous and uninterrupted growth in the number of small scale-domestic biogas installations in China.

China is also among the world's top countries in the number of large scale biogas generation. In 2010, from a total of 4700 large scale agricultural and 1600 industrial organic waste biogas installations, it produced 4 billion cubic meter biogas annually [9].

India stands second in the number of domestic biogas installations in the world. By the end of March 2011, the number of its domestic biogas installations reached 4.4 million. There are also a number of other Asian countries where domestic biogas installations are being expanded. Some of these countries with their total numbers of biogas installations constructed up to 2011include: Nepal (268,464), Vietnam (152,349), Bangladesh (26,311), Cambodia (19,173), Indonesia (7835), Lao Peoples Democratic Republic (2888) and Pakistan (2324) [14]. In comparison to its population size, Nepal has the largest number of biogas installations in the world [3].

Some African countries have also been working on the dissemination of biogas technology with renewed interest. The total numbers of biogas installations constructed up to 2011 in nine African countries, namely, Rwanda, Ethiopia, Tanzania, Kenya,