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Barriers to biogas dissemination in India: A review

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ABSTRACT

Biogas has emerged as a promising renewable technology to convert agricultural, animal, industrial and municipal wastes into energy. Biogas development can be integrated with strategies to improve sanitation as well as reduce indoor air pollution and greenhouse gases. Currently, the total biogas production in India is 2.07 billion m^3/year. This is quite low compared to its potential, which is estimated to be in the range of 29–48 billion m^3/year. Hence, this study aims to identify both technical and non-technological barriers impending biogas dissemination in India. Biogas dissemination is affected by various waste, renewable energy, and urban policies. Barriers were therefore identified individually for rural and urban biogas systems existing in India using decomposition analysis. The results show that type and importance of barriers vary strongly between biogas systems due to the difference in technology maturity, feedstock availability and quality, supply chain, awareness level and policy support.

1. Introduction

Biogas is a renewable energy source that is generated through anaerobic digestion of biodegradable organic feedstocks i.e. municipal and industrial wastes, animal and agricultural residues. Biogas contains high methane content (40–70%) that can further be upgraded to natural gas quality (75–99% methane content). The upgraded biogas can be injected into a natural gas grid or used as a transport fuel.

Anaerobic digestion of biodegradable organic wastes, besides providing energy and manure, offers several social and environmental benefits. Biogas contributes in reducing negative externalities associated with organic wastes such as groundwater and soil contamination, emission of local air pollutants like dioxins and furans as well as methane, a potent greenhouse gas (Kumar and Sharma, 2014; Lewis et al., 2017). Replacement of fossil fuels and untreated traditional solid biomass by clean fuel like biogas for cooking, lighting and electricity generation would also help in curtailing GHG emissions as well as indoor air pollution (Pathak et al., 2009). The nitrogen content in the slurry after anaerobic digestion enhances compared to untreated animal manure, thus can be used as organic fertilizer. Bio-fertilizer use in agricultural land would partly or fully offset the need for chemical fertilizers which itself have high energy demand during production (Katuwal and Bohara, 2009). Even though environmental, health and social co-benefits from biogas production are commonly recognized, there are several barriers to the deployment of biogas technologies that need overcoming.

Family-type small biogas systems predominantly exist in the rural areas with capacities ranging from 1 to 10 m^3 biogas per day. Animal manure and agricultural wastes are primarily used as feedstocks in household biogas digesters, producing biogas and bio-slurry that can be used as organic fertilizers. Mostly small-scale plants are managed by individual households to generate energy for self-consumption. On the other hand, large and industrial-scale biogas plants with capacity above 5000 m^3 biogas per day largely utilize municipal or industrial organic wastes to generate biogas which can further be utilized for electricity generation, heat and transport fuel. Family-type biogas plants are managed by the individual households requiring financial investment but only yielding non-monetary benefits i.e biogas used as cooking fuel substituting gathered fuelwood, whereas large-scale commercial biogas plants, managed by entirely private or public-private partnership aim to yield financial benefits by selling end-products i.e electricity, transport fuel or heat. Factors such as the macro environment, scale of production, utilization area and feedstock type differ widely between two biogas systems in India (He et al., 2013; Song et al., 2014). Given the differences between two biogas systems, it would be essential to carry out a comparative assessment of barriers to biogas dissemination at different scales.

Several support schemes such as the National Biogas and Manure Management Program (NBMMP), off –grid biogas power generation program, waste to energy program have been implemented by the government for biogas development in India (MNRE, 2015; Shukla, 2007). Regardless of these efforts, diffusion of biogas technologies is

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constrained by several financial, social and institutional factors (Rao and Ravindranath, 2002; Schmidt and Dabur, 2013). Few researchers have looked at the barriers to bioenergy diffusion in rural India (Rao and Ravindranath, 2002; Ravindranath and Balachandra, 2009; Vijay et al., 2015); while others have focused on stakeholder perspectives (Hassan et al., 2015; Zyadin et al., 2015) and bioenergy potential (Chandra et al., 2006a; Hiloidhari et al., 2014; Kumar et al., 2015; Rao et al., 2010). Several case-studies have also been carried out in the rural context to assess the success of biogas development programs (Bhat et al., 2001; Raha et al., 2014; Reddy, 2004). However, there is no study focusing on the barriers impeding the commercialization and diffusion of biogas technologies in urban areas at large and industrial scale.

Previous research studies have identified various barriers to biogas dissemination in different countries, for instance, UK (Adams et al., 2011), Europe (McCormick and Kaberger, 2007), Sweden (Lantz et al., 2007), China (Chen et al., 2012) and Thailand (Prasertsan and Sajjakulnukit, 2006), some from a stakeholder perspective (Adams et al., 2011), some from a system perspective (Lantz et al., 2007) and some from a multi-level perspective (Kamp and Bermúdez Forn, 2016) but none of these studies have compared the barriers prevailing in different biogas systems functioning at different scales. He et al. (2013) compared the performance of centralized and decentralized bioenergy systems in rural China and found that the costs of centralized bioenergy systems outweigh the overall benefits from the system. Barriers to biogas technologies diffusion in different countries stemming from previous studies are summarized in the Tables S.1 and S.2. The barriers mentioned in the literature have been classified into barriers affecting biogas dissemination in developed and developing economies.

Based on the review, it was found that barriers differ in different regions depending on the degree of market maturity and availability of natural resources like biomass, land, and water. Barriers such as low ambient temperature and water unavailability in arid regions are area specific (Shane et al., 2015) whereas others are specific to technological scale like lack of distribution infrastructure hindering the biogas expansion in a centralized system (Lantz et al., 2007). Socio-cultural barriers like objections towards using animal and human waste as raw material are very specific to the local values and culture (Rupf et al., 2015). Technical and informational barriers such as lack of technical capacity for construction and maintenance, competition from freely available firewood and lack of awareness mainly exist in rural areas in developing countries (Rao and Ravindranath, 2002; Rupf et al., 2015). Some barriers are specific to its utilization i.e transport fuel or heat production. High variation in the seasonal demand for heat acts as a barrier for utilization of biogas for heat production whereas a limited number of filling stations acts as a barrier for utilizing biogas as vehicle fuel (Lantz et al., 2007; Poeschl et al., 2010). This indicates that barriers to biogas penetration differ based on utilization area, substrate, resource potential, technological maturity, and scale. These factors may also vary among countries or regions.

To fill this gap, a comparison is done in this paper between the barriers to small-scale biogas technology dissemination in rural areas and large-scale biogas technology dissemination in urban India. The choice of India as a case is due both to the immense size of the country, the long history of a biogas policies, and the clear existence of biogas challenges at the rural (small scale) and the urban (large scale) biogas systems. Comparative analyses can then be used to propose strategies or policy interventions to deal with biogas development barriers specific to each system. Thus, this paper aims to address the following elicited questions. First, what are the barriers involved in the dissemination of biogas technologies in India? Second, are there any differences in the type of barrier among rural and urban biogas systems? Third, what changes in policy architecture are required to overcome the barriers in the respective biogas systems? This paper identifies the barriers to biogas dissemination in India based on an extensive literature review complemented by expert interviews.

The structure of the remaining paper is as follows. The first section highlights the history of biogas development policies in India to delineate the underlying drivers behind the current biogas development. The next section presents the methodology used to identify and analyze the barriers. Then we present the identified barriers followed by discussion and policy implications.

2. Evolution of biogas policies in India and their current status

Programs for promoting biogas technologies have been running since the 1970s. The first oil crisis in early 1970's made evident to the Indian policymakers that commercial energy would remain outside the economic reach of the rural as well as the urban poor (Deo et al., 1991). India was a net importer of oil products. The combination of global energy crisis together with the local energy shortages heightened the national energy security risk from rising costs of energy imports as well as the pressure on the national budget to meet the rising energy subsidy for domestic fuels, especially kerosene, used by the rural and urban poor for very basic cooking and lighting needs.

By the late 1970's, it was evident to the Indian policymakers that the traditional local energy resources such as agriculture waste, animal waste,and fuel-wood were no more freely available in many rural areas and there was a need to conserve and augment local resources. Several rural programs such as National Biogas and Manure Management program and off–grid biogas power generation program for providing renewable energy for cooking and lighting use. The biogas development program in 1981 was a part of a multi-prolonged approach adopted to alleviate the rural energy crisis (Shukla, 2007). Growing concerns towards solid waste management and climate change are the key drivers behind these policy initiatives to increase the biogas development in the urban areas. Fig. 1 represents the policy timeline specifying various initiatives taken by the government in last three decades to boost the waste to energy and biogas sector. Programs and initiatives for boosting the waste-to-energy sector from municipal solid waste and industrial wastes are of more recent origin; so it is difficult yet to determine the influence of new policies on the biogas technology deployment in the urban areas.

The rate of biogas dissemination is low in rural areas and the share of biogas in the fuel mix in rural households is insignificant. Around five million family biogas plants (40%) have been installed under the biogas development program against the total potential of 12 million domestic biogas gas plants estimated by the MNRE (CSO, 2014). In addition to family type biogas plants, 400 biogas off-grid power plants have been set up with a power generation capacity of about 5.5 MW (MNRE, 2015). The share of anaerobic digestion in biological waste treatment in urban areas is presently very low due to high capital cost and low revenue growth prospects compared to other competing waste treatment technologies. Currently, there are only 56 operational biogas based power plants in India, the majority of them are located in three states, Maharashtra, Kerala, and Karnataka (CPCB, 2013).

3. Methodology

A qualitative and systemic approach was used to identify barriers to biogas penetration in India. The following steps were taken to extract the relevant literature. First, a systematic search was conducted of research and review articles published after 1990 in the Scopus database. Fig. 2 presents the overview of the research protocol. Search terms used for identifying the relevant articles are mentioned in Table 1. Technical, potential and futuristic scenario studies on biogas were excluded after a manual screening (Table S.3). The gray literature related to biogas was also searched through Google and government portals(Table S.4).

As mentioned in the Section 1, few researchers have looked at the barriers impending large-scale biogas dissemination in urban India. Therefore, as a complement to the literature review, in-depth interviews with selected stakeholders were conducted to get insights needed to understand the root cause of each barrier particularly for biogas