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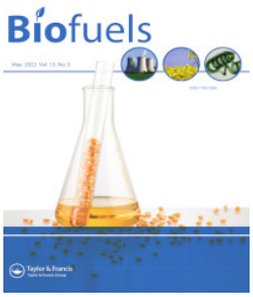

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Drivers and barriers to the implementation of biogas technologies in Bangladesh

A. S. M. Monjurul Hasan[a], Md Ahsan Kabir[b], Md Tanbhir Hoq[c], Maria T. Johansson[d] and Patrik Thollander[d]

[a]School of Information, Systems and Modelling, Faculty of Engineering and IT, University of Technology Sydney, Ultimo, NSW, Australia; [b]Department of Electrical and Electronic Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh; [c]Department of Electromagnetic Engineering, KTH Royal Institute of Technology, Stockholm, Sweden; [d]Department of Management and Engineering, Division of Energy Systems, Linköping University, Linköping, Sweden

ABSTRACT

In Bangladesh, despite available feedstock for producing biogas, the development of biogas production has been very slow. The objective of this research was to study the drivers for and barriers to biogas technology implementation in the country. As the research involved different types of stakeholders related to biogas production, the outcome provides clarity about the factors influencing the profusion of biogas production in Bangladesh. The outcome of the study identifies poor research and development, lack of coordination among stakeholders, an immature biogas market, lack of awareness and no feed-in tariff policy as the main barriers. In the case of drivers, the motivation of producing biogas as an efficient way of using waste, the availability of local experts, the attractiveness of a growing renewable energy market and the contribution of biogas technology in adaptation to climate change were found to be the most important factors. The study's outcomes are found to be similar to other studies from developing countries with similar socio-economic status. In accordance with the important drivers and barriers identified in this study, recommendations for increasing the diffusion of biogas in Bangladesh are also presented at the end of the article.

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KEYWORDS
Bioenergy; biogas; barriers; drivers; sustainability; Bangladesh

1. Introduction

Energy is considered to be the most significant factor in socio-economic growth and is strongly correlated with the holistic development of a country [1]. In many developing countries, there are governmental plans for economic development and coping with the increasing demands for energy, but there is also a desire to improve the energy supply and security and to reduce the environmental (mainly climate) impact of fossil-fuel-based energy production [2]. Bangladesh as a developing country has been experiencing an upward trend of economic growth in recent decades [3]. Due to the rapid growth of industrialisation, the need for energy is increasing as well. Bangladesh is relying mainly on fossil fuels to meet the energy demands [4]. Natural gas is the main energy source, supplying 57% of total primary energy demand, followed by oil [5]. Considering the problems associated with global warming and climate change, many countries are moving towards increased renewable energy adoption in their energy systems. Bangladesh is also taking steps to increase the share of renewable energy in energy supply. The use of renewable energy has been increasing gradually for the last few years in Bangladesh, especially in the biogas sector and small-scale solar power systems [6, 7].

Biogas is produced *via* the anaerobic digestion of organic material, and microorganisms are essential in the process. Different types of organic substrates can be used as raw materials, such as: sludge from wastewater treatment plants, manure, food waste, plant material, and process waters from food industries [8]. It consists of 60–70% methane (CH_4) and 30–40% carbon dioxide (CO_2), with the remainder being hydrogen sulphide (H_2S) and other trace gases [9, 10]. Biogas production is more flexible than that of other biofuels, because it can be produced from hydrocarbons, proteins or fats, including wet and secondary materials [11]. Biogas is one of the renewable energy sources that can provide a sustainable solution to increasing energy demand. Globally, in comparison with other renewable energy sources, such as wind and solar, the share of biogas production has been meagre [12], although over the last two decades, the stakeholders have become more motivated to produce biogas from waste and this trend is increasing globally. The highest energy-using countries, like the USA and China, have been expanding their biogas productions rapidly over the last few years [13]. The world's biogas production experienced a 3.5-fold increase from the year 2000 to 2011, which made it one of the fastest growing renewable energy resources in the twenty-first century [14].

There are many advantages of biogas, which include not only the generation of biogas to meet energy demand and bio-fertiliser, but also other socio-economic and environmental benefits [15]. It has the potential to contribute to

CONTACT Maria T. Johansson maria.johansson@liu.se Department of Management and Engineering, Division of Energy Systems, Linköping University, Linköping, Sweden

Table 1. Animal manure production in Bangladesh [30].

Animal manure type	Generation ratio (kg dry matter per capita per day)	Waste generation (kt/y)	Waste recovery (kt/y)
Cattle	2.90	24,180	14,887
Buffalo	2.52	1196	717
Goats	0.60	4680	2700
Sheep	0.45	39	214
Poultry droppings	0.04	1921	960

mitigating greenhouse gas emissions and improving the utilisation of crop nutrients. The integration of waste management systems to include biogas production can address many environmental issues, and such methods have been adopted in many countries [16]. One of the important factors is that biogas can be produced from a wide range of raw materials and thus can be customised for different geographical locations and economies. Bangladesh is to a high degree an agriculture-based economy and thus has a decent amount of local resources available to produce biogas on a large scale [13]. However, progress has been lacklustre for biogas production in the country given that there are plenty of suitable resources available for producing it [17, 18]. This inconsistency between amply available resource and paltry biogas production raises questions regarding the barriers to and drivers for biogas production in Bangladesh.

The aim of this paper is to study the barriers to and drivers for the implementation of the biogas solution in Bangladesh. The study is analysed in six major aspects of biogas production in the country:

- Technical
- Economic
- Social/Awareness/Behavioural
- Government/Policy
- Organizational and competency
- Market

Similar studies have been conducted in other countries; for example, studies in the United Kingdom, India and Ethiopia [19–22]. Also, there have been studies on biogas that accumulate results from a few different European and other countries [23–25].

However, to the authors' knowledge, there have not been any previous studies regarding the drivers for and barriers to biogas solutions in Bangladesh. From the available scientific literature, little is known about the factors influencing biogas production in Bangladesh. Despite of being an agriculturally based country, where plenty of biomass are available including the amount of generated municipal waste, it is significant to explore the barriers and drivers towards biogas diffusion. In addition, many other countries where plenty of biomass are available for biogas production can extract the lessons from this study. Thus, the objective of this research is to fill this gap. This will help to acquire a better understanding of the biogas scenario in Bangladesh. It will help stakeholders in the biogas industry to increase biogas production by reducing the barriers and reinforcing the drivers of biogas production. At the end of the paper, recommendations are discussed on how to increase diffusion of biogas in Bangladesh.

2. Biogas status in Bangladesh

Bangladesh is located in the North-Eastern part of South Asia, the total land area is 147,570 km^2 [26]. Among the major landscapes, floodplains occupy nearly 80% of the land area with hilly areas occupying almost 12%, and terraces the remaining 8% [13]. The flat part of this country is delta shaped. The hilly areas are mainly occupied by aboriginal people. The floodplain creates fertile land for cultivation and is the key reason behind Bangladesh's agriculture-based economy which has abundant resources to produce biogas [17].

Agricultural residue, animal manure and the organic portion of municipal waste are considered good sources for producing the biogas [27]. Agricultural residue is mainly collected from crops such as rice, wheat, sugarcane, maize and vegetables, 46% of the total bioenergy used in Bangladesh comes from rice husks, rice straw, sugarcane bagasse and jute sticks [28]. Animal manure is a mixture of organic material, moisture, and ash. Cattle, buffalo, goats and sheep are the main sources of animal manure in Bangladesh [29]. Table 1 shows the animal manure generation ratio, waste generation and waste recovery in Bangladesh.

Biogas is mainly used for cooking purposes in Bangladesh [31]. There are also examples of generating electricity by using biogas on a small scale [5]. Many developed countries are using biogas not only for power generation but also as biofuel for transportation [24]. Linköping, a city in Sweden, uses biogas as a mainstream fuel in the transportation sector [32]. The first biogas plant in Bangladesh was established in 1972 at the Bangladesh Agricultural University, Mymensingh, for demonstration purposes [31]. Table 2 shows the biogas scenario in Bangladesh. Domestic waste and manure are considered to be major feedstock for the domestic biogas plants. The domestic biogas potential in Bangladesh has been estimated to be 8.6 million m^3 [33]. Although there is potential for both biomass gasification power plants and biogas power plants, achievement in these sectors has fallen short of the potential [13]. Currently in Bangladesh, biomass and biogas power plants are generating about 2 MW of electricity [5].

IDCOL (a company established by the Government of Bangladesh), has invested 2.8 million USD in biomass-based technologies, which include biogas power plants, biomass power plants and biomass gasification plants. Up until December 2018, IDCOL had financed the construction of over 49,150 biogas plants all over the country [35]. It mainly finances two types of plants, brick and cement based, and fibreglass bio-digester based plants, with a daily gas production capacity of 1.2 m^3 to 25.0 m^3. This initiative saves 46,400 tonnes of firewood with a reduction of 185,000 tonnes of CO_2 emissions per annum. According to IDCOL's future plans, it aims to install 100,000 biogas plants in Bangladesh. Grameen Shakti is one of the prominent non-governmental organisations (NGOs) in the local biogas sector. They have installed 13,500 biogas plants so far [36]. There are many more NGOs (e.g. RSF, BRAC, BBF, GIZ, etc.) that are also working on biogas-related projects in Bangladesh [37].

Governmental policy plays a significant role in implementing any technology in a country [38]. The Ministry of

Table 2. Biogas situation in Bangladesh [5, 34].

Technology	Potential	Target	Achievement	Remark
Domestic biogas system	9 million m^3	100,000 biogas plants	Ongoing project	Most plants are wet fermentation based
Biogas power plants	380 MW	5 MW	Less than 1 MW	Wet fermentation based

Power, Energy, and Mineral Resources of Bangladesh finalised a policy in 2008 on overall renewable energy, which included biogas technology as a renewable energy technology, but at this moment there is no specific approved policy for biogas diffusion in Bangladesh [13].

3. Methodology

The study is exploratory and employing grounded theory. A qualitative and systemic method is designed to identify the barriers and drivers. In context, the study is conducted in five steps. At first, an intensive literature review and practical cases were studied to prepare a questionnaire in seven knowledge areas such as technical, economical, government/policy, social/awareness/behavioural, organizational & competency and market. Then, the questionnaire was sent to stakeholders working in the biogas sector mainly categorized as biogas feedstock suppliers, biogas process plant developers/owners, government/policy organizations and the academicians. A total of 55 respondents' feedback have been analysed and data reliability was check by the Cronbach's alpha test. Finally, the most important barriers and drivers were identified and ranked. The detail methods are discussed below and presented in Figure 1.

3.1. Intensive literature study

Literature studies have been used to understand the energy system of Bangladesh, biogas production, present biogas status in Bangladesh. The search items were 'biogas and drivers', 'biogas and barriers', 'biogas status in Bangladesh' and 'energy system in Bangladesh'. The scientific databases such as Web of Science and Scopus were used to search the relevant papers. Initially, a wide search of scientific articles and other relevant sources were done, and literature was categorized and prioritized in the later phase as per relevancy. A total of 100 scientific papers and 10 practical cases are studied for this research project. However, while integrating the scientific papers at this research, few exclusion criteria were maintained. Table 3 presents the expulsion criteria of the research:

3.2. Preparation of questionnaire

A questionnaire was prepared based on the literature review and real cases in Bangladesh. The questions were derived from the literature review of 100 scientific papers and analysis of 10 real cases of biogas projects. We visited multiple biogas projects implemented in different areas in Bangladesh in an attempt to understand the challenges these projects faced. Our literature study focused on similar studies in other countries. Based on the literature review and multiple intensive discussions with the participants (e.g. academician, biogas plant developer, policy makers and NGOs), the potential barriers and drivers addressing a Bangladesh context were formulated. A similar case study was conducted to find out the drivers and barriers in the field of bioenergy diffusion in the United Kingdom [20]. Notably to mention that the study of United Kingdom [20] inspired up-to some extent to design and initial formulization of the questions.

A total of 40 questions addressing potential barriers and 27 questions addressing potential drivers to biogas technology implementation in Bangladesh in technical, economic, social and policy areas were formulated. The questions were asked in a hierarchical manner. In the questionnaire, drivers and barriers are divided into seven sections: Technical, Economic, Social/Awareness/Behavioural, Government/Policy, Organizational and competency and Market. The barriers and drivers in the questionnaire are reproduced in Table 4.

3.3. Selection of stakeholders for survey

The questionnaire was sent to 80 different stakeholders. They were selected based on three criteria such as working experience in biogas sector, proficiency in technical knowledge and working as a government or biogas/renewable policy development organization. In this survey, the stakeholders working experience was considered as minimum of 10 years except for the government policy organizations. For example, Sustainable Renewable Energy Development Authority (SREDA) – principle government renewable energy policy development organization in Bangladesh was formed in 2013 but currently plays a significant role in renewable energy development in Bangladesh. In addition, survey data is collected from Infrastructure Development Company of Bangladesh (IDCOL) – a specialized government owned company in Bangladesh which is not only responsible for financing renewable development projects but also peer to peer management among field level organizations to international development organizations. IDCOL built around 48,300 biogas plant, LGED developed 1142 projects, Bangladesh Council of Scientific and Industrial research (BCSIR) completed 22,000 projects. These projects are implemented mainly for cooking in rural houses and plant size was small.

3.4. Data collection, analysis, reliability check

In this research a total of fifty-five stakeholder's responded among the 80 different stakeholders that the questionnaire was submitted to. The number of feedstock supplier and field level biogas plant operator responders was thirty and those are closely affiliated with IDCOL. The local organizations that replied to this questionnaire after having several group discussions with its members and, hence one single feedstock supplier sample reflects multiple peoples thought which made this evaluation stronger. A total of fifteen international and local NGOs including Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ),

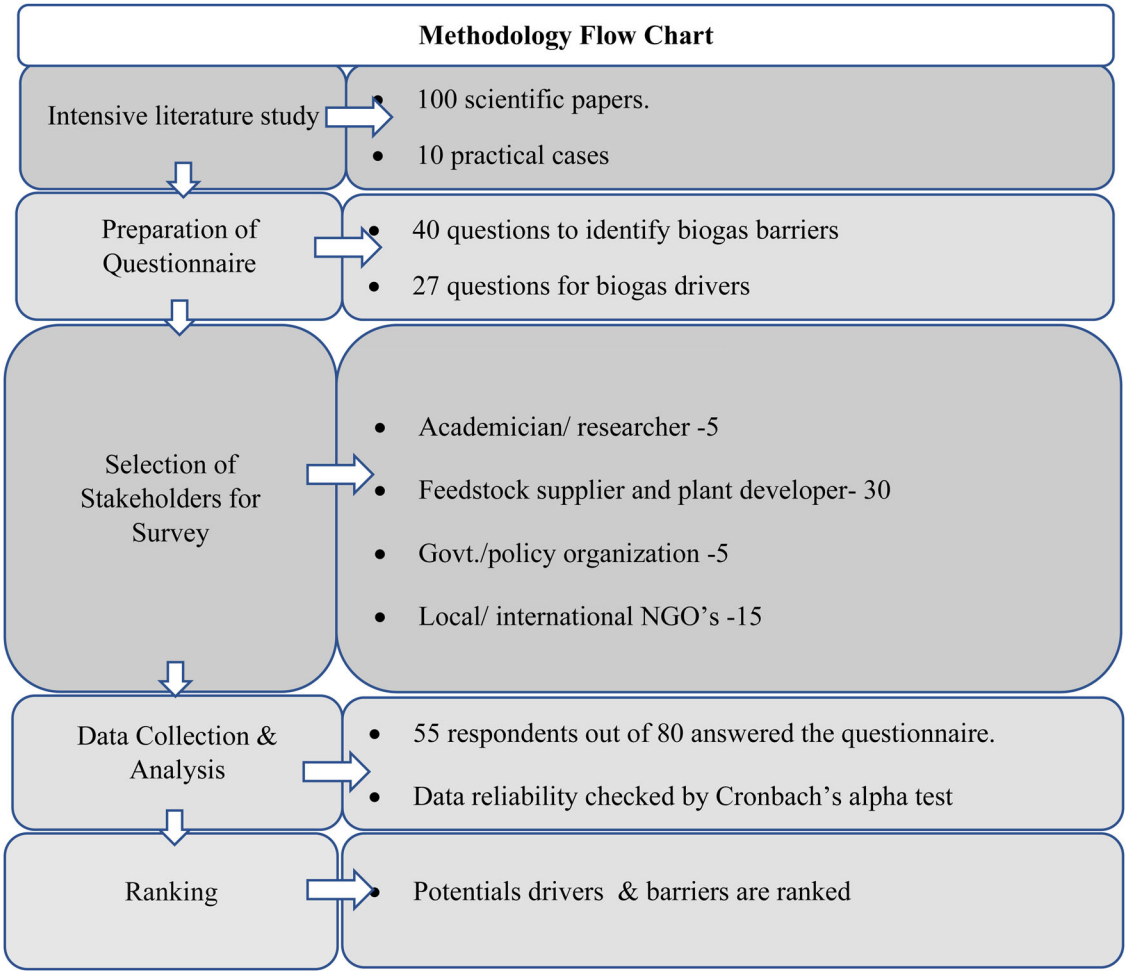

Figure 1. Chronological steps of the methodology of this research.

Table 3. Exclusion criteria of the literature.

Exclusion criterion	Remark
Criterion 1	The article uses 'biogas' term only in title and does not incorporate drivers and barriers to implementation
Criterion 2	The article uses 'biogas' only as a part of the future research direction or future perspective
Criterion 3	Articles deals only with biogas production technology
Criterion 4	Availability of full texts

Practical Action, Grameen Shakti and BRAC feedback have been added considering their contribution as the major biogas plant developers in rural Bangladesh. Five government organizations such as SREDA, IDCOL, Local Government Engineering Department (LGED), Bangladesh Bank (regulatory authority of green financing) and Bangladesh Council of Scientific and Industrial Research (BCSIR) participated in this survey. Finally, five senior academician and researchers participated in the survey. The number of participants from academia is not quite high in this research. We have contacted more than ten researchers but got response from five researchers only. Notably to mention that few of the academicians are working on biogas in Bangladesh. However, in our study the participated academicians have versatile record to work in the field of biogas.

The data is collected by sending questionnaire by e-mail. The respondents were initially contacted *via* phone calls, emails were sent later on with the details of the research and the questionnaire and physical meeting was also needed especially for rural organizations to explain the research objective. Respondents were requested to assess each of the barriers and drivers on a five-point Likert scale: 'unimportant', 'somewhat important', 'important', 'very important' and 'extremely important'. The options were rated from 1 for 'unimportant' to 5 for 'extremely important'. Thinking about the broad experience of the respondents, legitimacy of the view of them can be considered as significant. However, the collected data was validated over telephone. Furthermore, the collected data was analysed and reliability of the data was checked by Cronbach's alpha test. In this study, the value of Cronbach's alpha is 0.805 which reflects adequate internal coherence of the data series

3.5. Ranking of barriers and drivers

The influential issues on biogas barrier and drivers are ranked and presented in results. The arithmetic means have been taken consideration only on the responses of the numbered Likert scale. However, the discrepancies in perceptions have not been considered in this study. The results were normalized in the later phase that ranges from 0 to 1.

4. Barriers to a biogas solution

4.1. Technical barriers

The results show that the most important technical barriers to biogas technology implementation were '*Lack of waste treatment and storage facilities*', '*Lack of feedstock supply*' and '*Planning and installation issues*'. These barriers were marked

Table 4. The barriers and drivers to biogas technology that were included in the questionnaire.

Category	Barrier	Driver
Technical	Planning and installation issues	Efficient methods of waste utilisation
	Lack of waste treatment and storage facilities	Variety of feedstock use for bioenergy
	Poor quality of feedstock	Specific application-based
	Water unavailability	Customised technologies suitable for processing local feedstock
	Nonexistence of proven technology	
	Lack of feedstock supply (resource availability)	
	Uncertainty in production of feedstock	
	Physical resource limitations (land availability)	
Economic	Competition with other investments	Profitable return on investment
	Uncertain return on investment	Availability of financial support
	Uncertainties about receiving financial support	Possibility of cost savings on energy
	High initial investment	Availability of cheap feedstock
	Uncertain development and operational costs	Bank loans at low interest rates
	Lack of investment incentives	Ensuring business value from biogas projects
	Low energy cost for end users	Third party financing
Government/Policy	Unclear and complex issues	Meeting governmental renewable energy target
	Lack of financial policy	Adaptation to climate change
	Insufficient attention from government	Specific target for biogas production
	Bureaucratic complexity	
	Lack of concrete biogas policy	
Social/ Awareness/ Behavioural	Perceived negative environmental impacts of feedstock	Possible reduction in carbon emissions
	Lack of sufficient knowledge on biogas usage	Other environmental benefits (other than CO2 reduction)
	Lack of awareness about the policies, technology etc.	Attractiveness of growing renewable energy market
	Political unwillingness	Increased bioenergy interest from end-users
	Resistance to change	Political willingness to embrace green energy
	Socio-economic differences between urban and rural population	
Market	Unsettled energy market	Market diversification or opportunity
	Immature biogas market	Bioenergy use versatility
	Low primary-end-user demand	Threat of rising natural gas price
	Lack of participation in global carbon market	
	Inadequate private participation	
	Competition with fossil fuels	
Organizational & Competence	Lack of technical experts/services	Availability of technical experts
	Poor research & development	Environmental certification system
	Lack of coordination in biogas projects	People with real ambition
	No unique platform for biogas stakeholders	Environmental image
	Lack of feedstock experience	Long-term energy strategy

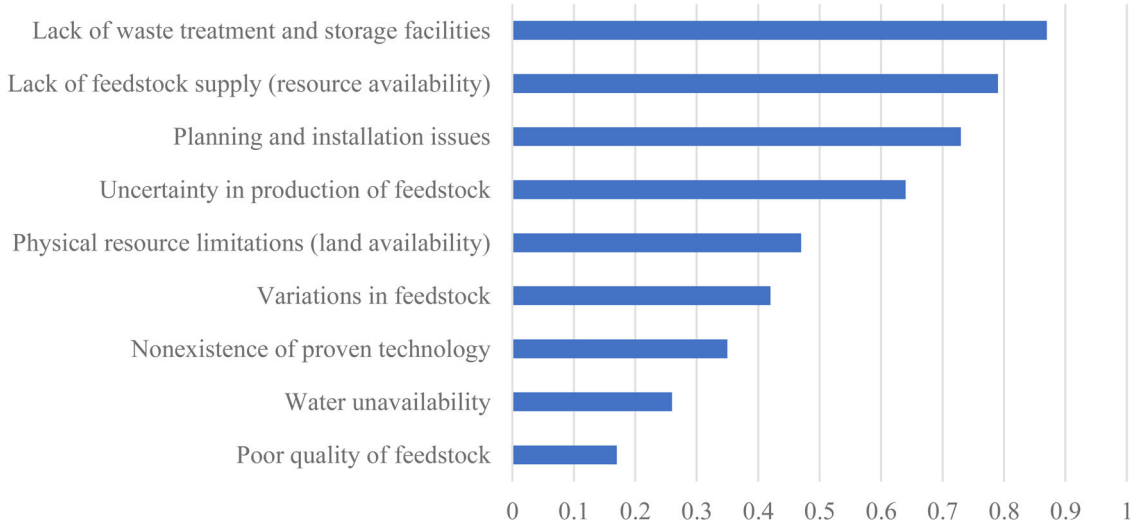

Figure 2. Technical barriers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

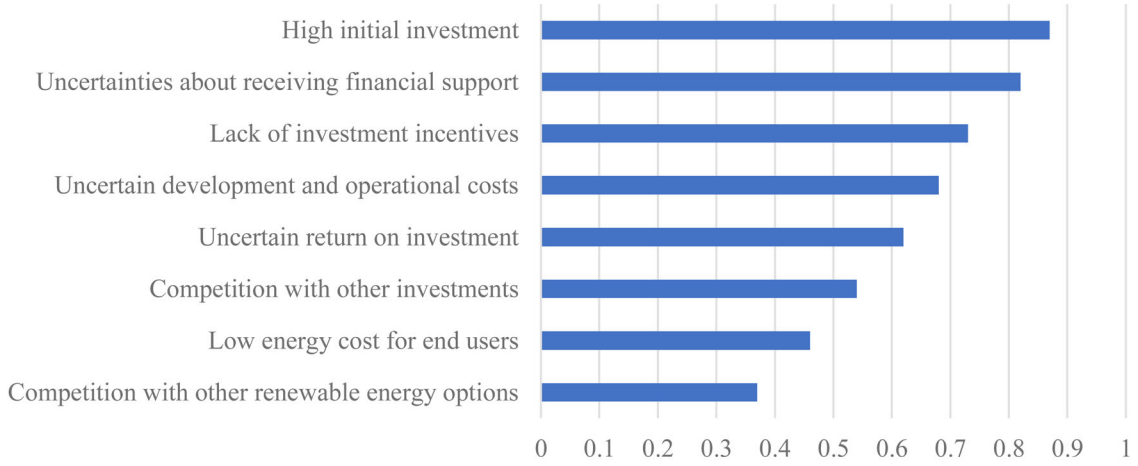

Figure 3. Economic barriers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

by 42 participants out of 55. The other identified barriers were '*Uncertainty in production of feedstock*', '*Physical resources limitation (land availability)*' and '*Variations in feedstock*'. It was found that the two lowest ranked barriers were '*Water unavailability*' and '*Poor quality of feedstock*', which were rated by only one respondent as important. Figure 2 shows detailed responses from the study.

4.2. Economic barriers

'*High initial investment*' was identified as the most important barrier, followed by '*Uncertainties about receiving financial support*' and '*Lack of investment incentives*'. These barriers were marked as top barriers by 28 participants out of 55. The other important barriers were '*Uncertain development and operational costs*' and '*Uncertain return on investment*', followed by '*Competition with other investments*'. The lowest ranked barrier was '*Competition with other renewable energy options*'. Figure 3 presents the different economic barriers for biogas implementation in Bangladesh.

4.3. Social barriers

The results show that the most important social barriers were '*Lack of awareness about the policies, technology and its benefits*' and '*Political unwillingness*', followed by '*Resistance to change*'. These barriers were marked as top barriers by 37 participants out of 55. The lowest-ranked social barrier was '*Perceived negative environmental impacts of feedstock*'. Figure 4 shows the detailed responses from the study.

4.4. Policy barriers

'*No feed-in tariff policy*' was identified as the most important policy barrier to biogas implementation in Bangladesh. Eighteen participants identified this as the most significant policy barrier. The other important policy barriers were '*Lack of concrete biogas policy*' and '*Insufficient attention from government*', followed by '*Lack of financial policy*'. The lower ranked policy barriers were '*Bureaucratic complexity*' and '*Unclear and complex legislative issues*'. Figure 5 presents the detailed responses for the study.

4.5. Market barriers

'*Immature biogas market*' was identified as the highest ranked market barrier from twenty participants for biogas implementation in Bangladeshi market. The others

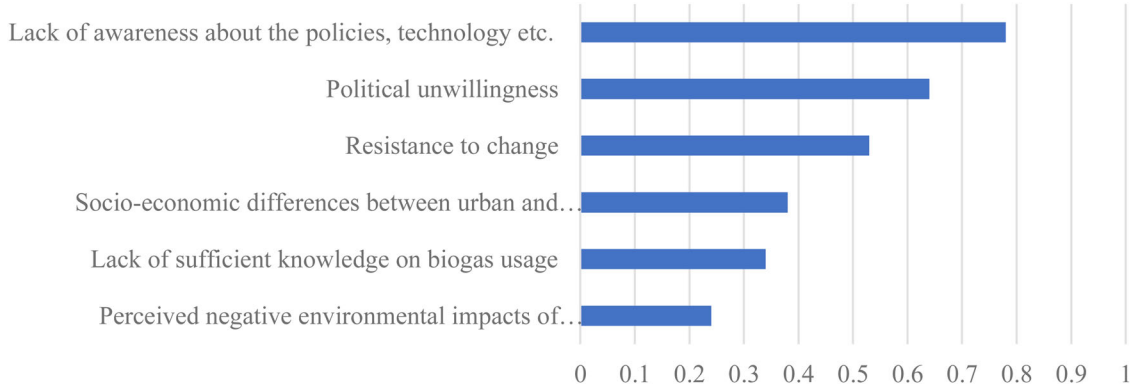

Figure 4. Social barriers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

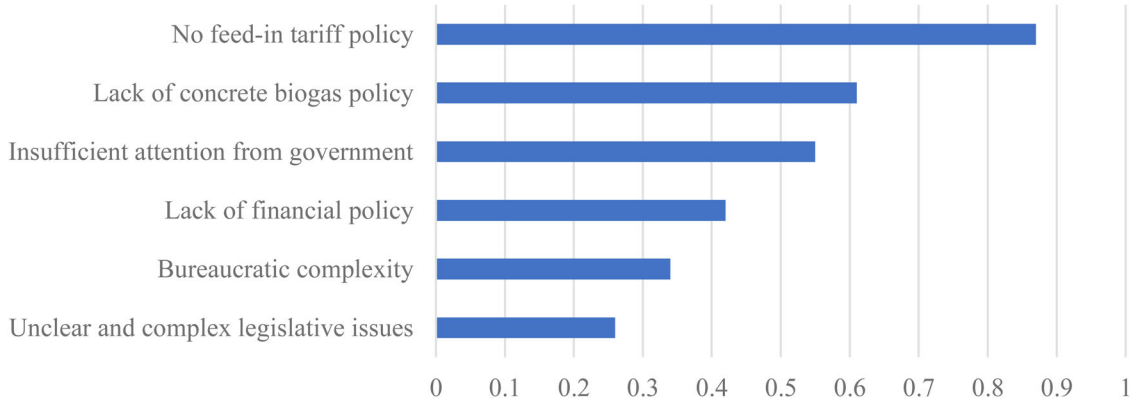

Figure 5. Policy barriers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

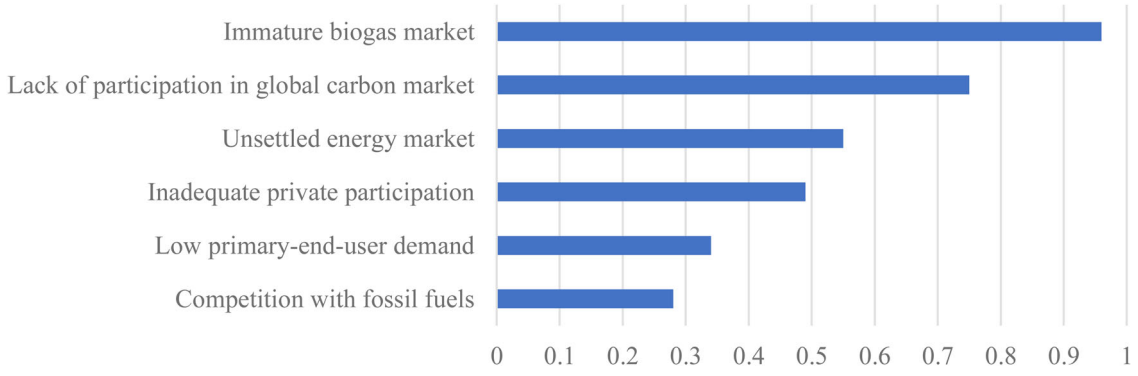

Figure 6. Market barriers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

significant barriers are identified as '*lack of participation in global carbon market*' and '*unsettled energy market*'. '*Low primary- end-user demand*' and '*Competition with fossil fuels*' are found as less important in Bangladesh biogas market. Figure 6 presents detailed responses for the study.

4.6. Competency and organizational barriers

'*Poor research and policy*' was identified as the highest ranked market from twenty participants to biogas implementation in Bangladeshi market. The others significant barriers are identified as '*lack of coordination in biogas projects*' and '*lack of technical experts/services*'. '*No unique platform for biogas stakeholder*' is found as less important in Bangladesh biogas market. Figure 7 presents detailed responses for the study

5. Drivers for biogas solutions

5.1. Technical drivers

The results show that the most important technical drivers were '*Efficient form of waste utilisation*' followed by '*Variety of feedstock for bioenergy (resource diversification)*'. These drivers were marked as top drivers by 41 participants out of 55. The lowest-ranked technical drivers were '*Specific application based*' and '*Customised technologies suitable for processing local feedstock*'. Figure 8 shows the detailed responses from the study.

5.2. Economic drivers

'*Ensuring business value from biogas project*' was identified as the most important driver to implementing the

Figure 7. Organization and competency barriers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

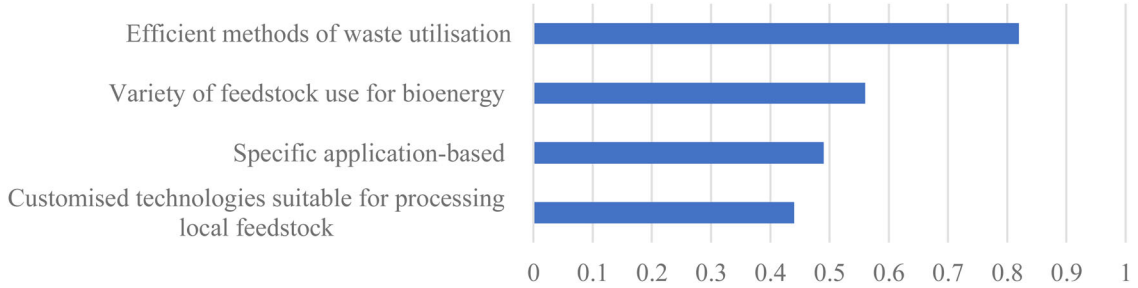

Figure 8. Technical drivers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

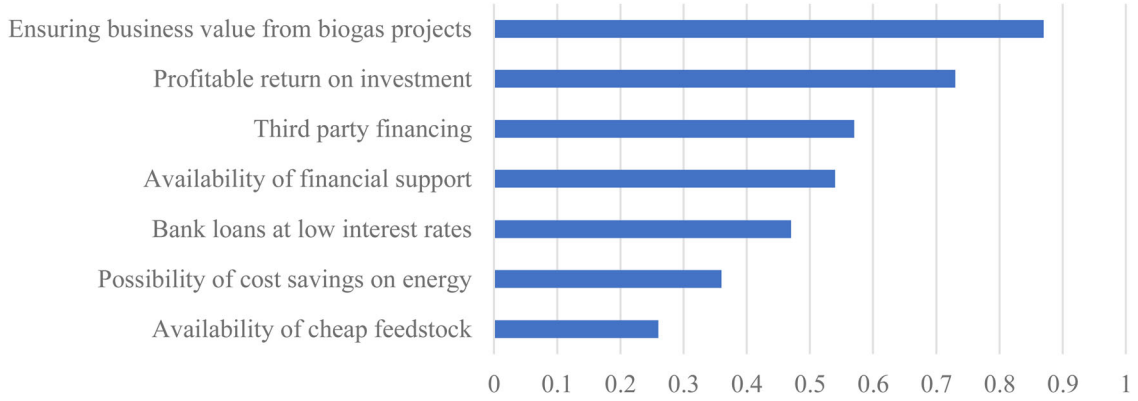

Figure 9. Economic drivers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

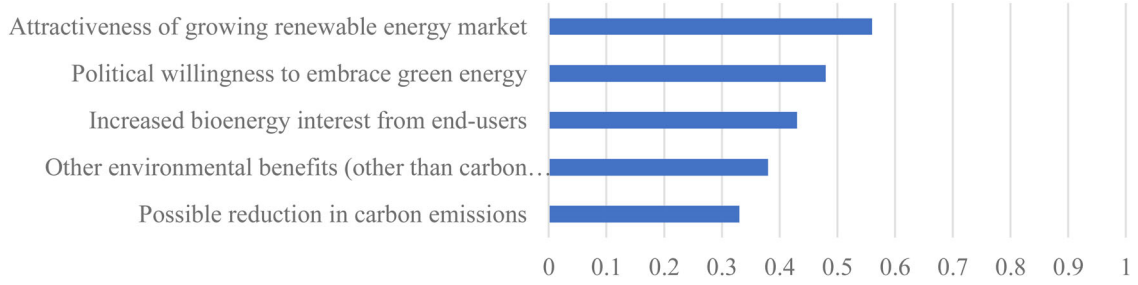

Figure 10. Social drivers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

biogas solution in Bangladesh. Twenty-nine participants out of fifty-five, identified this driver as the most significant. The other significant economic drivers were '*Profitable return on investment*' and '*Third party financing*', followed by '*Availability of financial support*'. The lower-ranked economic drivers were '*Possibility of saving cost of energy*' and '*Availability of cheap feedstock*'. Figure 9 presents the detailed study of economic drivers from this study.

5.3. Social drivers

The results show that the significant social drivers were '*Attractiveness of growing renewable energy market*' and '*Political willingness to embrace green energy*', followed by '*Increased bioenergy interest from end-users*'. These drivers were marked as top drivers by 22 participants out of 55. It was found that the lowest-ranked social driver was '*Possible reduction in carbon emissions*'. Figure 10 shows the detailed responses from the study.

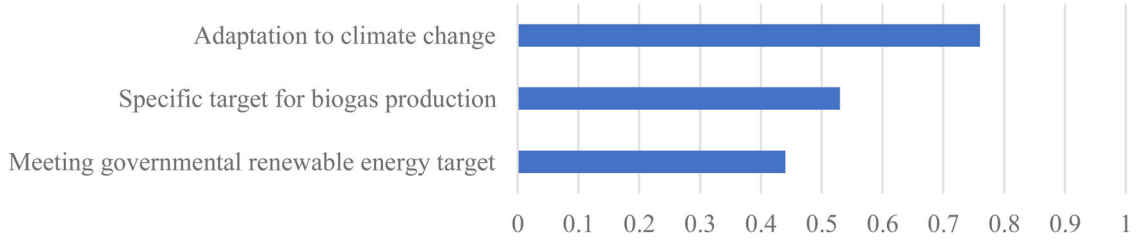

Figure 11. Policy drivers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

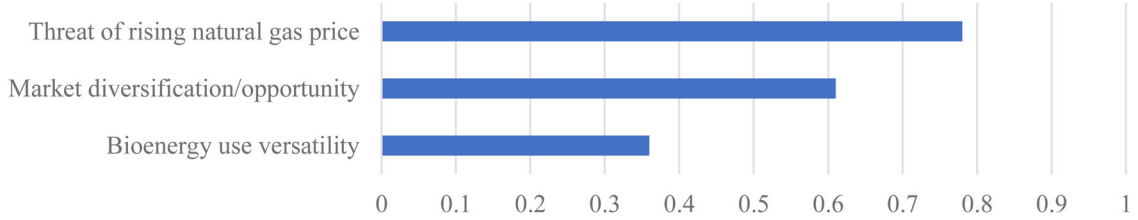

Figure 12. Market drivers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

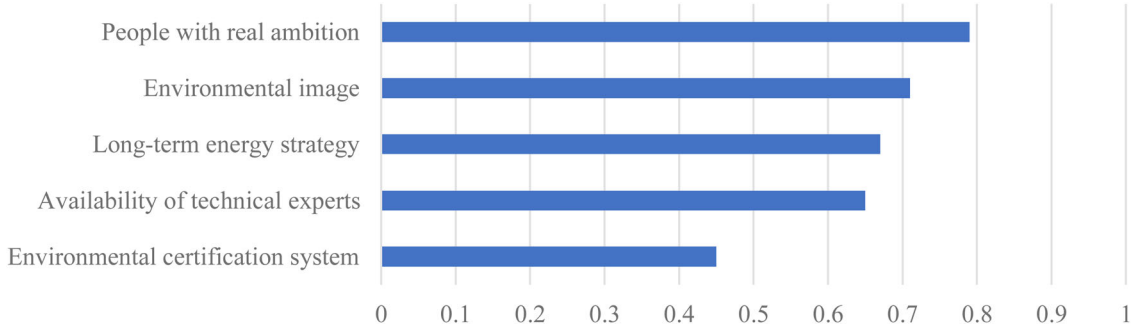

Figure 13. Market drivers to biogas implementation, where respondents were asked to rank the perceived barriers from '1: Unimportant' to '5: Extremely important'.

Table 5. Top ranked barriers and drivers to biogas technology in Bangladesh.

Top ranked barriers and drivers		
Category	Barriers	Drivers
Technical	Lack of waste treatment and storage facilities	Efficient form of waste utilisation
Economic	High initial investment	Ensuring business value from biogas project
Social/ Awareness/ Behavioural	Lack of awareness about the policies, technology and its benefits'	Attractiveness of growing renewable energy market
Government/Policy	No feed-in tariff policy	Adaptation to climate change
Organizational and Competence	Poor research and policy	People with real ambition
Market	Immature biogas market	Threat of rising natural gas price

5.4. Policy drivers

'*Adaptation to climate change*' was ranked as the most significant policy driver to biogas solution implementation in Bangladesh. Thirty-eight participants ranked this as the most significant policy driver. The lower-ranked policy driver was '*Meeting governmental renewable energy target*'. Figure 11 presents the policy drivers for biogas solutions in Bangladesh.

5.5. Market drivers

'*Threat of rising natural gas price*' was ranked as the most significant policy driver to biogas solution implementation in Bangladesh. Thirty-eight participants ranked this as the most significant policy driver. The lower-ranked policy drivers were '*Market diversification opportunity*' and '*bioenergy use versatility*'. Figure 12 presents the policy drivers for biogas solutions in Bangladesh.

5.6. Competency and organizational drivers

'*People with real ambition*' was ranked as the most significant policy driver to biogas solution implementation in Bangladesh. Thirty-eight participants ranked this as the most significant policy driver. The lower-ranked policy drivers were '*availability of technical experts*' and '*Environmental certification system*'. Figure 13 presents the policy drivers for biogas solutions in Bangladesh

6. Discussion

Biogas production is an important part of sustainability goals in developing countries. A recent review concerning biogas development in Europe shows that it has seen significant growth in recent years which has mainly been driven by favourable support schemes [24, 39, 40]. These support schemes are missing in Bangladesh, and our study

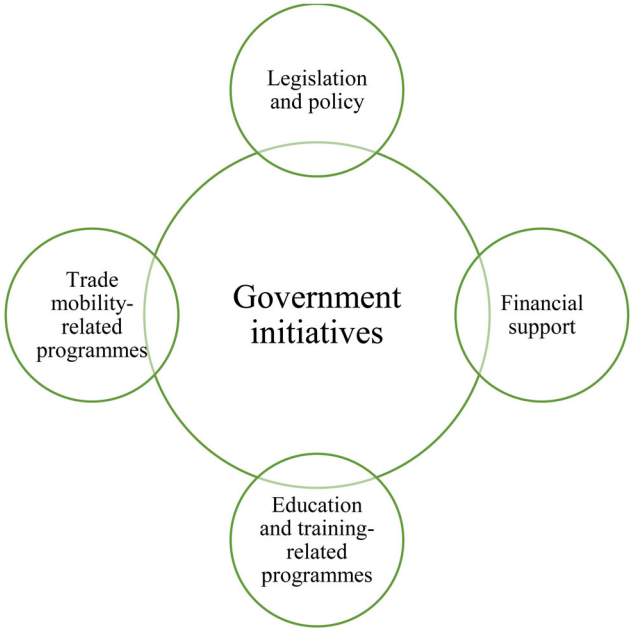

Figure 14. Government initiatives for the diffusion of renewable energy technologies (inspired by Ref. [13]).

shows that this constitutes a main barrier. The critical findings of our study are presented at Table 5.

If the outcome of this study is compared with similar research in other developing countries, similarities are found. In the United Kingdom, the most critical barriers are all related to economic considerations and the most important driver is reducing carbon emissions [20]. A review article on the diffusion of biogas in several developing countries found high installation and maintenance costs to be the major barrier [41]. Another review on barriers to biogas dissemination in India was found, and this research shows that high initial investment, lack of awareness about the policies, technology and its benefits and lack of coordination between different stakeholders are important barriers [19, 42]. The outcome of this study also found these barriers in the case of Bangladesh. In Nigeria, a lack of support from government in areas of policy, the provision of subsidies, soft loans and tax incentives are the major barriers to biogas diffusion [11]. The high up-front cost of bio-digester has been the major barrier for biogas diffusion in Senegal [43]. It was observed that in developing countries economic concerns are the major barriers [44–46]. These similarities can be attributed to the similar socio-economic structure of developing countries.

6.1. Recommendation to diffuse biogas in Bangladesh

The dissemination of renewable energy technologies such as biogas requires several actors to be engaged from the beginning; this incorporates government, future proprietors and individuals. These are the principal actors needed to actualise and maintain the innovation [47]. Adequate local information and skills ought to be likewise accessible for execution, support and future repair work [48]. The legislature is an imperative performer for the dissemination of ecological advances in a nation [49]. The other imperative actors are: public and private associations, NGOs, the media and so forth. Governmental initiatives can impact upon and actualise the implementation of a sustainable technology [48]. Figure 14 demonstrates the governmental initiatives that incorporate legislation and policy, financial help, instruction and training, exchange portability, related projects and so forth.

Legislation and policy play critical roles in the dispersion of renewable energy technologies [50, 51]. Bangladesh published its renewable energy policy in December 2008 and this policy incorporates modalities and systems, financial and other incentives and tariff regulations [13]. In the policy, it has been stated that the share of biogas will be expanded, but it is difficult to get clear guidelines about the biogas feedstock supply and utilisation.

Financial incentives act as an effective programme for the implementation of renewable energy technologies [1]. The Government of Bangladesh can give financial support to promote renewable energy technologies from multiple points of view to people and organisations. This budgetary assistance can take the form of a subsidy, a loan, tax exemption and so on. Sometimes, the capital and operational expenditures become high for renewable energy technologies. Financial help can tackle this issue and motivate the stakeholders to move forward with environmental technology implementation and building of infrastructure such as tank stations, pipelines etc.

Our study shows that lack of awareness about policies and technology are an important barrier. Educating the people is a vital part of the dissemination of renewable energy technologies [52]. The people ought to be educated and instructed about the multiple advantages and benefits of biogas solutions. Despite having a good amount of feedstock for biogas production, numerous individuals in Bangladesh are unaware of the bio-fertiliser which is a by-product of the biogas production process. This bio-fertiliser is an excellent source of plant supplements. The government should involve local NGOs and the media to inform people about the numerous benefits of biogas solutions and to motivate them to utilise it. Public interest and co-operation are also very significant in the diffusion of environmental technologies into a community [48]. It has been observed that, without public support and co-operation, numerous environmental diffusion projects have failed in many countries.

Creating a market is another critical aspect of the diffusion of renewable energy technologies [49]. It is essential for organisations to have favourable market circumstances so that companies can sustain their businesses in the energy and environmental sector. Trade mobility plays a significant role in this regard. The government should create an environment for companies in which they can bring their new ideas and technologies to market and continue their business. It is a challenging task for a government to diffuse environmental technologies like biogas unless it can engage and encourage commercial companies to become involved in this sector [47].

There are many examples for successful biogas diffusion and lessons can be learnt. Sweden is becoming an exemplary model for biogas diffusion by integrating their waste management system for biofuel production [53, 54]. Germany has been successful for a long time to implement biogas based transportation system and power generation in many regions [55]. The governmental subsidy was the main driver to disseminate the biogas sector in Thailand [56]. India and Pakistan, two south Asian neighbouring

countries of Bangladesh are focusing on community based waste management system for biogas production [42, 57]. Financial subsidies scheme and proper waste management system have been the prime reasons for successful biogas diffusion in many regions of China [58]. In Ghana, government is focusing on pilot scale projects at the biogas sector [38]. Proper waste management system, increase of institutional capacity and policy are the actors to spread the biogas technology at Bolivia in a larger scale [59]. The researchers identified many actors for successful biogas diffusion, though special focus was given to policy instrument.

7. Conclusion

Bangladesh is lagging in the biogas sector despite having adequate resources to produce and utilize biogas on a large scale. This paper aimed to study barriers to and drivers for biogas development in Bangladesh. The preliminary study is novel as to the author's awareness, no previous study has been published revolving around this theme from Bangladesh's perspective. Despite its novel character, the authors would like to draw attention to the fact that the results emanate from 55 respondents.

To summarise the responses of the participants, the six major areas of concern mentioned in the introduction regarding biogas production in Bangladesh can be used. From a technical perspective, the respondents identified lack of waste treatment and waste storage facilities as the main barriers, while the motivation of producing biogas as an efficient way of using waste was found to be the important drivers for biogas production. On the economic side, the high initial investment is the major barrier, and the drivers portray the expectations of the stakeholders about mitigating these barriers; for example, ensuring a return on investment from biogas projects. From a social/awareness/behavioural perspective, the main barrier is the lack of awareness about the policies, technologies and the benefits of biogas production and the main driver are the attractiveness of a growing renewable energy market. In policy-related matters, the lack of a feed-in tariff policy for biogas production is the main barrier, whilst the contribution of biogas technology to the adaptation to climate change is the most important driver. However, in the competency and organizational perspective, poor research and policy is the top-ranked barrier. In contrast, people with real ambition towards biogas technology implementation has been found as the most significant driver in this category. Immature biogas market is identified as the topmost barrier in the market area, whilst the threat of rising natural gas price is marked as the most significant driver at this category. The outcome of the survey shows that the most important barriers to biogas production in Bangladesh revolve around the lack of a structured policy and economic uncertainties, while the drivers are mainly related to sustainability and reducing carbon emissions.

There have been no other studies regarding identifying the drivers and barriers to the implementation of biogas technology in Bangladesh. Our study becomes even more critical while the Government of Bangladesh is planning to increase the share of renewable energy in the coming days. Notably, the biogas sector has the potential to be one of the major renewable energy sources in Bangladesh. Our work is the first step in understanding the underlying causes behind lack of development in the sector despite plenty of material resources, this also identified gaps in research and can work as a guide to future works in this domain. As the barriers are identified in this work, future research in this sector may include an analysis of how different barriers can be removed. For example, as the high initial investment is one of the major barriers, an investigation regarding reducing the initial cost by using cheap and locally available technologies and material can be conducted. Besides, analysis can be conducted regarding the possible success of public-private partnership investments in biogas sector with the rising natural gas price. It requires several actors to be involved in the successful implementation of biogas. As the government is considered as the primary stakeholder to diffuse biogas in any region, the proper focus must be maintained from the Government of Bangladesh in regards of policy, financial framework, waste management system and incorporation of other institutions in this field. Therefore, the future research scope should encompass the policy framework integrating multidimensional stakeholders, precisely the technical and financial modalities. Furthermore, it will certainly be interesting to explore the biogas value chain system keeping the focus on the circular economy and beyond.

Disclosure statement

The authors declare no conflict of interest.

ORCID

A. S. M. Monjurul Hasan http://orcid.org/0000-0003-0333-1449
Maria T. Johansson http://orcid.org/0000-0003-0360-6019
Patrik Thollander http://orcid.org/0000-0002-4823-9905

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